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Degree: Master of Arts

Year This Degree Granted: 1999

University of Alberta

Biological Differentiation of Eneolithic and Bronze Age Populations of Baraba, Western Siberia: Cranial Nonmetric Variation at the Sopka-II Burial Site

by

Darryl A. Bereziuk ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Arts

Department of Anthropology

Edmonton, Alberta

Spring, 1999

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled ‘Biological Differentiation of Eneolithic and Bronze Age Populations of Baraba, Western Siberia: Cranial Nonmetric Variation at the Sopka-II Site’ submitted by Darryl A. Bereziuk in partial fulfillment of the requirements for the degree of Master of Arts.

In memory of my father,
Alex Elias Bereziuk

I have fought a good fight, I have
finished my course, I have kept the faith

II Timothy. 1v: 7

Abstract

This study utilizes cranial nonmetric analysis and the 'skeletal population' approach to examine processes of biological differentiation and genetic change in human populations inhabiting the Baraba region of Western Siberia during the Eneolithic, Krotovo and Andronovo Developed Bronze Age. Data on 52 nonmetric traits have been collected from 308 adult crania from the Sopka-II site. Only 36 of the 52 original traits display sufficiently consistent intraobserver scoring consistency. A distributional analysis of these traits across all samples reveals no directional differences in trait incidence between the sexes or sides of the body. The most variable traits are used to calculate Mean Measure of Divergence (MMD) statistics between the synchronic and diachronic cranial samples. The MMD results are further examined by cluster analysis. The results of the biological distance and cluster analysis are used to test a series of hypotheses formulated from a review of existing skeletal and archaeological research of the region.

The MMD results display no evidence for ancestral relationships between Eneolithic populations of Baraba and the Developed Bronze Age burial groups from Sopka-II. The patterns of morphological divergence between four Krotovo burial groups suggest the occurrence of at least two episodes of rapid biological change. Several lines of evidence suggest that these biological events are associated with internal processes of social stratification within the Krotovo community and the appearance of intrusive populations to the region. The evidence includes the appearance of labour intensive kurgan burials in the divergent Krotovo cemeteries, higher levels of bilateral symmetry within the kurgan cranial samples and consistent morphogenetic affinity between the Andronovo crania and one of the Krotovo kurgan groups. In the absence of comparative biological data, these conclusions must remain tentative and should be viewed as hypotheses to be tested by future research.

Acknowledgements

The completion of this thesis and my Masters program would have been impossible without the support, assistance and guidance of numerous individuals. First I would like to thank my thesis advisors, Dr. Owen Beattie and Dr. Andrzej Weber, for their continued support of this project over the last four years. Dr. Weber provided not only the opportunity for research in Siberia but also supported me with assistantships and funding for the radiocarbon dates. I am also indebted to the Graduate Scholarship Committee and the Canadian Circumpolar Institute at the University of Alberta for providing substantial financial support for my residency in Edmonton and field research in Siberia. Dr. Fiona Bamforth has graciously accepted the responsibilities of external examiner for which I am grateful. I also wish to express my gratitude to Dr. Pam Willoughby for accepting to chair the defense. I am also indebted to Darlene Bagstad, Marlys Rudiak, Gail Mathew and Kelly Nicholson-Scheer for their friendship and cheerful assistance over the past several years. Thank you all very much. I would also like to acknowledge the support of my Russian colleagues at the Institute of Archaeology, Ethnography and History in Novosibirsk. Dr. V. I. Molodin kindly permitted me to study the human skeletal collections from Sopka-II. Dr. T. A. Chikisheva and E. G. Shlakova offered me endless assistance in the osteology laboratory. Thanks must also be given to E. I. Derevianko and A.V. Adveev for their friendship and hospitality during my stay in Akademgorodok. Thanks to Cidália Duarte, Julie Ross, Cheryl Bereziuk and Bruce Ball for reviewing earlier drafts of this thesis. I would like to thank my mother, Mary Bereziuk, and sister, Cheryl Bereziuk, for their continued support of my academic career and especially for giving me the strength to continue during the difficult times. To Cidália, you are the embodiment of kindness and integrity and I thank you for your continuous encouragement and the very special times. To Celeste, your love and companionship over the last two years have helped me to gain new direction and better perspective in my life. Special mention must be given to Andrew Johnson for being a great friend and to his company, Raventech Software, for supplying me with programs that greatly simplified the statistical analysis. I have had the opportunity and great pleasure of making many wonderful friends over the course of my Masters program. I must thank Pam Mayne, Dave Link, Bob Dawe, Jack Brink, Bruce Ball, Mike Telford, Arne and Leslie Carlson, Kevin Brett, Ping Lai, Murielle Nagy, Franca Boag, Shauna McGarvey, Derek Honeyman and so many others. Forgive me if I have missed anyone. I thank you all for making the last five years an enjoyable and enlightening experience.

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CHAPTER 1: INTRODUCTION AND BACKGROUND

1.0 INTRODUCTION

The investigation of biological evolution and variation within human populations, past and present, is a topic that has traditionally been of interest to physical anthropologists. This line of inquiry has proven particularly challenging when studying past human groups because of the limited nature of the data base, and is confined primarily by the morphological variation manifest in human skeletal remains. Studies of the 19th and early 20th century focused upon the subjective description of human osteological structure and variability. This initial period of study resulted in the accumulation of considerable knowledge concerning skeletal variability within and between human populations, but lacked a standardized approach that could produce comparable results between different researchers. Over the course of this century, physical anthropologists have increased the value of human skeletal analysis in studies of biological distance by adopting formalized methods of analysis that allow for the quantitative assessment of biological evolution and variation of past human groups. Theoretical advancements in the study of biological distance have accompanied these methodological advancements.

Contemporary biological distance studies employ both metric and nonmetric manifestations of the human cranium, postcranium and dentition in order to provide measures of human biological variation in the past. The traditional approaches used analyses of metric or measurable variation in the human skeleton. The popularization of this method and the application of sophisticated multivariate statistics to this standardized database has allowed researchers to develop morphological profiles of human skeletal populations and to compare the biological distance within and between groups. Early interpretations generally followed a 'racial typological' model in which metric data, principally of the skull, were used to place populations into preconceived and static 'racial' groups. In conjunction with the development of biochemical and physiological research on extant human populations, physical anthropologists increasingly applied analytical theory and method developed primarily for the study of extant biological populations to human skeletal research (Molto 1983:1). Associated with this shift has been the adoption of the 'biological population' model which is founded upon genetic and evolutionary principles. In this approach, the focus is upon the identification of the

microevolutionary processes (*i.e.*, mutation, natural selection, gene flow and genetic drift) affecting the genetic constitution and variation of past human groups. The application of skeletal nonmetric methods in studies of human biological distance has occurred relatively recently and is associated with the above theoretical shift. Following the identification of a genetic component in the expression of these minor skeletal variants in mice (Grüneberg 1952), a voluminous literature has been dedicated to assessing the value of nonmetric traits for making inferences about biological relationships within and between past human groups.

The central assumption behind contemporary biological distance research is that skeletal variation is genetically determined. However, it has become widely accepted that size and trait expression in skeletal tissues are due to complex, multifactorial interactions between many genes as well as environmental, developmental and physiological influences (Corruccini 1974). As such, the etiologic basis for most morphological variation observed in the human skeleton is largely unknown. This complexity has prompted Molto (1983:8) to assign the term 'morphogenetic affinity' to skeletal determinations of human biological relatedness in order to highlight the inherent difficulties in attributing genetic relatedness from patterns of phenotypic expression. Thus, the focus of biological distance research has been to identify genetically relevant skeletal variability as opposed to those traits primarily influenced by environmental, developmental or physiological factors. Consequently, a large proportion of skeletal research has focused on methodological refinements that reduce the effects of nongenetic influences on the results of biological distance studies. In addition, since both metric and nonmetric skeletal expressions display different aspects of the underlying genotype, both methods are considered viable alternatives for examining morphogenetic variability between prehistoric skeletal series. In fact, as stated in the 'non-specificity' hypothesis, the incorporation of both analytical methods is preferred since the maximum amount of available morphological information is utilized (Ossenberg 1976).

1.1 Research Objectives

This thesis will utilize cranial nonmetric analysis and the 'skeletal population' approach to examine the processes of biological differentiation and genetic change that may have occurred in human populations inhabiting Western Siberia during the Eneolithic and Developed Bronze Age. The analysis is based upon cranial nonmetric

data obtained skeletal collections of the Central Baraba region. Cranial nonmetric traits were examined on skeletons from four burial grounds of Central Baraba although the majority of analytical samples were drawn from the large series of Eneolithic and Developed Bronze Age human skeletons excavated from the Sopka-II site. As such, the present work is limited in its regional focus.

The Eneolithic and Developed Bronze Age encompass a time of significant cultural transition in Western Siberia represented by major culture-historical transformations and socioeconomic shifts. Based mainly upon typological analyses of pottery and metal technology as well as associated shifts in mortuary practices, three major culture-historical periods have been identified for the region: the Eneolithic (*i.e.,* Copper) Age, the Samusko-Seyminskiy Epoch of the Developed Bronze Age, and the Andronovo Epoch of the Developed Bronze Age (Kosarev 1987; Molodin 1977, 1985). Evidence of increasing cultural complexity in Western Siberia over this time include the earliest evidence of horse domestication and wheeled transportation (Matyushin 1986), the introduction of copper and bronze metallurgy, the adoption and subsequent development of a pastoral food producing economy, increasing settlement sizes, the first evidence of settlement fortification and increasing social stratification as suggested by the appearance of labour intensive kurgan (*i.e.,* earth mound) burials (Dergachev 1989).

The social, technological, and economic developments associated with the Early Metal period in Western Siberia resulted in the initial, intensive exploitation of the steppes by human groups. The steppes in the south of Western Siberia rapidly transformed into an independent center of cultural development from what before was a mere contact zone during the Neolithic (Bobrov 1988). It is believed that the highly-mobile nature of these steppe-adapted cultures greatly influenced subsequent cultural developments in the adjacent forest and forest-steppe regions of Western Siberia (Masson and Taylor 1989). In the Barabinsk forest-steppe, cultural influences from Eneolithic and Bronze Age steppe populations upon autochthonous populations with roots in the local Neolithic greatly affected cultural-historical and economic developments in the region (Molodin 1977, 1985). The continuous influence of steppe populations from the west and southwest are thought to have culminated in the widespread cultural consolidations that occurred across vast tracts of southwestern Siberia, including Central Baraba, during the Andronovo Developed Bronze Age (Dergachev 1989). However, it remains unclear

whether the diffusion of technological and economic innovations during the Eneolithic and Developed Bronze Age were associated with major population movements into and out of Central Baraba that would contribute to simultaneous alterations in the gene pool of local populations. The extent to which these cultural interactions resulted in interbreeding is impossible to determine without the examination of skeletal remains from the respective archaeological cultures.

The present work represents the first application of cranial nonmetric biological distance analysis to Eneolithic and Developed Bronze Age populations of Western Siberia. Although cranial nonmetric methods of analysis have been introduced into the Soviet anthropological literature (Movsesyan *et al.* 1975), biological distance studies in present day Russia have tended to disregard this type of analysis, relying more on data obtained from measurable or metric attributes and general morphological characteristics of the human skull. Recently, several studies have been published which examine the history of ethnic origins in the Barabinsk forest-steppe and include craniometric analyses for skeletal series of the Baraba region (Polos'mak, *et al.* 1989; Molodin & Chikisheva 1988). These studies suggest that the history of ethnic development in Baraba is associated with a long and complex process of admixture between 'Mongoloid' populations in the taiga zones to the north and east and 'Europoid' populations to the south and west. Given the complementary nature of cranial metric and nonmetric analyses in human biological distance studies, it appears timely and useful to apply the latter method to Eneolithic and Developed Bronze Age skeletal series of Central Baraba in order to further investigate the nature of these hypothesized biological interactions.

The theoretical foundation of this thesis is the 'biological population' model. A large portion of the analysis focuses upon methodological aspects of cranial nonmetric analysis with the goal of minimizing observer error and eliminating nongenetic influences inherent in the nonmetric data. The latter consideration will include the analysis of sex and side differences in order to detect directional biases in the expression of nonmetric traits that are potentially related to environmental, developmental and physiological influences. A univariate statistical analysis of trait variability will identify those nonmetric variants of most utility in differentiating between the skeletal samples. Further analysis of the refined nonmetric data will utilize a multivariate biostatistical approach in order to forward meaningful genetic interpretations of the morphogenetic

data. Two levels of biological distance analysis have been performed on the skeletal nonmetric data:

1. the study of biological affinity and differentiation between several large burial grounds belonging to the Samusko-Seyminskiy Developed Bronze Age epoch (*i.e.,* Krotovo culture) discovered at Sopka-II (synchronic focus)[1]; and,
2. the assessment of biological affinity and differentiation between culture-historically distinct populations identified at the Sopka-II burial ground (diachronic focus).

The results of these analyses provide new information concerning morphogenetic change in the human populations inhabiting Central Baraba during the Eneolithic and Developed Bronze Age. The analysis attempts to show whether or not the changing material culture and subsistence strategies observed in the archaeological record over these times are related to simultaneous population migrations. The two levels of analysis are intended to comprehensively examine the biological differentiation that exists between the cranial samples and, perhaps, to gain insights into the microevolutionary processes that operated upon these prehistoric populations. On a more general level, the study introduces biological information that contributes to ongoing debates concerning the relative importance of population migration, independent innovation, cultural diffusion and environmental change for stimulating the cultural transformations observed in the Eneolithic and Developed Bronze Age archaeological record of Western Siberia. The information from this research, in conjunction with other nonmetric, metric, linguistic and molecular biological evidence, can be used by future investigators to construct models of genetic change and population migration for the entire region of Western Siberia.

1.2 Thesis Organization

The following two sections of the chapter will provide background information concerning nonmetric traits and the study of biological distance as well as an outline of the prehistory of the Baraba region with particular emphasis on the Eneolithic and Developed Bronze Age. Chapter 2 presents the sites, the skeletal populations and

[1] The burial grounds are separated spatially and also display distinctive characteristics of mortuary behavior in what is thought to represent a relatively synchronic use of the site.

sampling procedures employed in this study and includes a discussion concerning the theoretical problems associated with the 'skeletal population' approach in studies of biological distance. Chapter 3 presents the methods of trait selection and scoring and examines distributional aspects of the nonmetric data. Chapter 4 examines the trait by trait variability of nonmetric expression across the Siberian samples and presents the results and discussion of the diachronic and synchronic biological distance analysis. This is followed by a summary and conclusion chapter.

2.0 NONMETRIC TRAITS AND THE STUDY OF BIOLOGICAL DISTANCE

Nonmetric traits (*i.e.,* epigenetic or quasi-continuous skeletal variants) are minor morphological features observed for their presence or absence on the human skeleton. Over 200 nonmetric variants have been described for the skull (Hauser and De Stefano 1989; Saunders 1989). Unlike continuously distributed metric variables, nonmetric traits are generally expressed in a few discrete states and are difficult to measure on an interval scale. Thus, early researchers applied the terms 'discontinuous' and 'discrete' to nonmetric traits believing that the variants occur in only two alternative expressions. It is now generally accepted, however, that most nonmetric traits express more than two discrete states (Hauser and De Stefano 1989:1). Since the incidence of these traits vary among different populations, the study of nonmetric variants in prehistoric skeletal series is thought to allow determinations of the biological interrelatedness of past human populations.

2.1 Historical and Theoretical Background

The recognition of cranial nonmetric variation extends back at least three centuries to the work of early European anatomists who noted the anomalous nature of these minor skeletal variants (Hauser & De Stefano 1989:1). Generally, these early observations were regarded as curiosities and, therefore, lacked an explanatory framework for trait expression. Later, during the 19th century, human biologists focused upon the description and classification of nonmetric skeletal variants and began to study the underlying nature of nonmetric trait manifestation (Corruccini 1974). During this time, many traits were employed in studies of comparative anatomy and phylogeny associated with the development of the 'theory of recapitulation' (Saunders 1978:6). The

recapitulation theorists regarded many nonmetric skeletal variants as evolutionary vestiges of morphological features observed in lower mammals. This evolutionary explanation for nonmetric trait expression was embraced by the contemporary polygenist school who endeavored to hierarchically rank the major human 'races' by comparing nonmetric variation between human populations. These researchers believed that the expression of primitive traits in certain 'races' was evidence of their racial primitiveness in comparison to other human groups (Saunders 1989). Despite the eventual rejection of recapitulation and polygenist theories, these scientific traditions were responsible for initiating research into the underlying nature of nonmetric trait expression and for advancing the study of nonmetric traits from a descriptive to a comparative pursuit.

The rejection of the polygenist theories in the late 1920's resulted in the rise of population-based human research that was grounded upon the principles of genetics and evolution. The concurrent rise of quantitative cranial metric studies and research into biochemical and physiological polymorphisms in extant human populations led to a declining interest in the study of nonmetric skeletal variation (Saunders 1978:7). In fact, the eventual establishment of nonmetric traits as markers of genetic affinity in humans arose largely from the work of geneticists researching nonmetric variants in wild and experimental animals, most notably mice (Berry 1963; Grüneberg 1951, 1952, 1955; Searle 1954a, 1954b).

Grüneberg (1952), while studying the absence of third molars in mice, discovered that an underlying continuous distribution, the size of the tooth rudiment, was directly responsible for trait expression. In other words, the continuous variable of size was found to be directly responsible for the discrete manifestations of third molar presence or absence. He applied the term 'quasi-continuous' to nonmetric traits in order to express his conviction that a similar, though generally unidentified, continuous distribution was responsible for the expression of all other nonmetric traits. This study first demonstrated the departure of nonmetric genetic expression from simple Mendelian patterns of inheritance. Genetic crosses between inbred strains of mice further suggested that trait expression was the result of the additive affects of numerous genes, thus displaying a 'polygenic' pattern of inheritance (Grüneberg 1952).

According to the 'quasi-continuous' model, such traits are suggested to be under the control of an underlying, normally-distributed genetic continuum (*i.e.*, continuous

variable for trait liability), simultaneously influenced by the action of numerous genes and non-genetic factors, that maintains a physiological threshold for trait expression resulting in only a few potential phenotypic outcomes. Individuals whose genetic liability surpasses the physiological threshold manifest the trait; for those who do not, the trait is absent (*cf.*, Figure 1.1). By adding more than one physiological threshold along the continuum of genetic liability, this model was adapted to account for unilateral versus bilateral trait expressions (Ossenberg 1981) and traits displaying several discrete stages (Hauser & De Stefano 1989:7).

These genetically coded liabilities for trait expression can vary in the presence of different modifying genes or environmental, developmental or physiological influences. In fact, many nongenetic variables were found to have some effects on discrete trait expression in mice, including sex, litter size, maternal age, postnatal environment, gestation length and diet (Deol and Truslove 1957; Searle 1954b). The term 'epigenetic' has been applied to nonmetric skeletal variants in order to emphasize the significant influence of these external factors in their phenotypic expression.

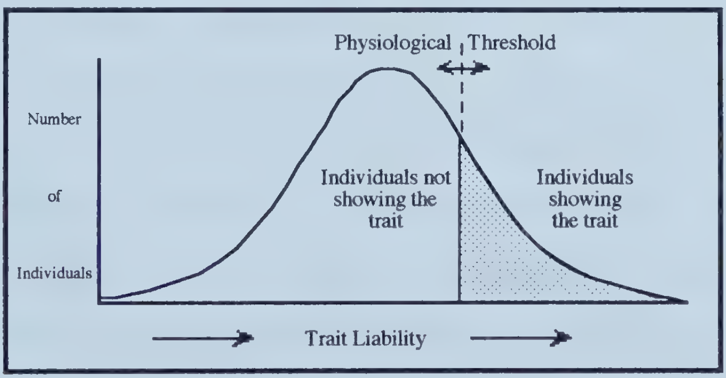


Figure 1.1 Diagram showing the continuous distribution for trait liability and its relationship to a superimposed physiological threshold for trait expression (adapted from Hauser and De Stefano 1989:5).

The theoretical approach of nonmetric biological distance studies assumes that these variants in humans are primarily under genetic control (Saunders 1989). This view is supported by several lines of indirect evidence that will be examined below. Despite this common assumption, few studies on human populations have provided *direct* evidence demonstrating genetical determinance for the majority of nonmetric traits. This situation

is largely due to the absence of appropriate human skeletal samples and should not detract from the reasonable likelihood for large genetic components directing nonmetric trait expression in humans. As opposed to the abundant skeletal materials available when working with prolific animals such as mice, it is difficult and rare to obtain large series of human skeletons with known family relationships suitable for direct heritability analysis. Berry and Berry (1967) considered the results of early human pedigree analyses as evidence for the genetic basis of nonmetric trait expression since many studies reported Mendelian-like patterns of inheritance. However, the actual trait frequencies in these studies rarely matched the expected Mendelian ratios which, in the absence of the 'quasi-continuous' model for trait inheritance, led most researchers to conclude erroneously that 'incomplete penetrance' of the gene controlling trait expression was responsible. These claims were discredited when it was recognized that 'quasi-continuous' (*i.e.*, polygenic) expression of nonmetric variants along family lines could often simulate the pattern of inheritance expected for Mendelian models (Cheverud & Buikstra 1981a).

In one of the few studies conducted on documented human skeletal populations, Sjøvold (1984) found heritability estimates for nonmetric traits to be either negligible or nonexistent. By contrast, several studies on living human populations, aided by radiographic techniques and larger sample sizes, have demonstrated familial concentrations and high heritability estimates for several traits (Johnson *et al.* 1965: mandibular and palatine torus; Saunders & Popovich 1978, Saunders *et al.* 1976: atlas and clinoid bridging; Torgersen 1951a, 1951b: metopism, inca bone and sutural anomalies). However, the genetical signficance of other nonmetric traits have been challenged. Several researchers have demonstrated the significance of nongenetic factors in trait expression including the possibility of major gene effects (Grüneberg 1963, as cited in Saunders 1989:105) and environmental determinants (Corruccini 1974: highest nuchal line; Halffmann *et al.* 1992: palatine torus; Mayhall 1970: mandibular and palatine torus; Melbye 1969: marginal, malar and zygomaxillary tubercles; Rösing 1984: accessory infraorbital and zygomaticofacial foramen).

The inherent difficulties associated with heritability studies in human populations has led researchers to pursue more indirect lines of evidence. One commonly cited criterion for inferring underlying genetic control is the observation of a variants appearance in an individual before birth (Hauser & De Stefano 1989). Although

arguably providing evidence for heritability, this hypothesis fails to account for the potential influences of the prenatal environment on trait expression. In addition, Berry and Berry (1967) have argued that the constant incidence of certain nonmetric variants within specific races and the similar frequencies between related races also support the claim for heritability.

Without question, however, the most commonly cited evidence for the heritability of nonmetric traits in humans has come from studies on experimental animals that have confirmed an underlying genetic basis for the expression of analogous traits (Sjøvold 1977a). Self and Leamy (1978), continuing the earlier work of Grüneberg (1951, 1952, 1955), studied the heritability of a large number of nonmetric traits in a random-bred population of mice. The study found generally low heritability estimates for 11 cranial nonmetric traits, thought to be the result of the recent emergence of the strain from its parent population, but concluded that the amount of additive genetic variation observed was in support of the 'quasi-continuous' model for trait inheritance. The only other direct study of heritability was provided by Cheverud and Buikstra's (1981a, 1981b) analysis of 14 cranial nonmetric traits in free-ranging populations of the rhesus macaque. Over one-half of their resulting heritability estimates were greater than 0.5, indicating a considerable amount of additive genetic variation in the population and generally moderate heritabilities for the traits. Both the direct and indirect evidence discussed above provides compelling evidence for the existence of a significant genetic component underlying nonmetric expression in humans. At the same time, these studies have demonstrated the complexity of nonmetric trait expression involving the interaction between genetic and nongenetic factors.

A series of publications by Wood Jones (1931 a,b,c; 1934) is widely considered as the first to explore the potential of skeletal nonmetric variants for contributing to studies of biological distance between human populations. However, Laughlin and Jorgensen (1956) were the first researchers to apply the method in a comparative biological distance analysis of Greenlandic Eskimo populations. Soon afterwards, Brothwell (1958) contributed to these developments with an analysis of metric and nonmetric variability between numerous, world-wide skeletal populations. Despite the originality of these early studies, they did little to stimulate further interest in the use of skeletal nonmetric traits for human population research. It was not until Berry and Berry (1967) presented a

standardized list of traits for the human skull and introduced the C.A.B. Smith's Mean Measure of Divergence statistic, that allowed the calculation of average distances between population samples, that similar human biological distance studies became popular.

2.2 Methods of Research in Human Populations

An expanding literature in physical anthropology has been devoted to methodological issues associated with nonmetric biological distance analysis. Generally, these studies have focused upon maximizing the effectiveness of skeletal nonmetric analysis by identifying those aspects of the analytical method that potentially dilute genetic information about past human populations. These include:

1. the evaluation and standardization of trait definitions, descriptions and scoring procedures;
2. the examination of distributional aspects of nonmetric skeletal expression concerning the effects of side, age and sex differences on the analysis of biological distance as well as the examination of intertrait association; and,
3. the refinement of statistical techniques and criteria that aid in interpopulational comparisons.

The first two methodological issues will be briefly discussed below. A discussion concerning current developments in statistical techniques and their utility for determining biological affinity or differentiation between skeletal samples will be presented with the biological distance analysis in Chapter 4.

The foundation of nonmetric biological distance studies is the recording and analysis of the empirical data, the skeletal nonmetric variants. Despite early assumptions about the 'quick and easy' scorability of skeletal nonmetric variants (Berry & Berry 1967), several critiques have noted the incomparability of published studies because of unstandardized trait nomenclatures, trait descriptions and scoring practices. These studies demonstrate the need for further evaluation and standardization of the methods of skeletal nonmetric trait analysis. The absence of standardized trait nomenclatures, especially between European and North American researchers, led Cesnys and Pavilonis (1982) to propose a unified terminology of nonmetric characters based upon the Parisiana

Nomina Anatomica proposal. In addition, several authors (Cesnys & Pavilonis 1982; Corruccini 1974; De Stefano *et al.* 1984; Thoma 1981), noting the prevalence of unstandardized scoring procedures, have recognized the need for providing detailed trait descriptions and etiologic information in order to limit the use of different scoring thresholds when conducting nonmetric trait analysis. A major contribution to the identification and explanation of skeletal nonmetric variation was provided by Ossenberg's (1969) categorization of cranial nonmetric traits based upon arrested (*i.e.*, hypostotic) or excessive (*i.e.*, hyperostotic) bone formation, soft tissue relationships (*i.e.*, foraminal traits), as well as other regional factors. More recently, the publication of Hauser and De Stefano's (1989) *'Epigenetic Variants of the Human Skull'* has provided the most current and comprehensive reference atlas and guide for the analysis of cranial nonmetric traits, presenting standardized trait descriptions, detailed etiologic information concerning the traits, and scoring thresholds that correspond to the biological realities underlying trait expression.

Demonstrating the need for further diligence in the standardization of terminology and scoring criteria, studies on intra- and inter-observer scoring reliability have reported very high deviations for at least several nonmetric traits. Inter-observer error tests have discovered that partial trait manifestations are presently incomparable between observers and are subject to considerable error even by one observer (Saunders 1978; Molto 1983). The scoring of accessory foramina and traits that reflect tendinous or ligamentous attachments appear to be the most problematic (De Stefano *et al.* 1984; Molto 1979; Ossenberg 1969). Finnegan (1978) suggests that the elimination of problematic variants from trait lists and the tightening of trait descriptions will assist in eliminating intra- and inter-observer error. Despite this, it remains clear that the assessment of intra-observer error should be standard procedure in any study, particularly if samples are scored at widely spaced intervals (Molto 1979; De Stefano *et al.* 1984).

2.2.1 Intrapopulational Variation

Despite compelling evidence suggesting a significant genetic component underlying nonmetric trait expression in humans, it is also well established that environmental, developmental and physiological factors play a significant role in the *nature* of their development. Thus, before meaningful biological distance comparisons between populations can proceed, it is necessary to examine, on a number of different levels, the

intrapopulational heterogeneity of nonmetric traits in order to identify and eliminate those traits whose development are significantly influenced by hormonal, developmental, environmental or physiological factors. This is generally facilitated by an examination of trait incidences between the sexes, different age groups and the sides of the body. In addition, it is important to determine the independence of occurrence in the side to side expression of bilateral traits as this factor greatly affects the appropriateness of the chosen scoring method. As well, it is necessary to examine the data for significant associations between nonmetric variants since trait independence is a statistical requirement for the multivariate comparison of population samples. Each of the above aspects of intrapopulational variation and their relevance to nonmetric biological distance analysis is discussed below.

Side Difference

Nonmetric skeletal traits located lateral to the median plane can be absent or occur unilaterally or bilaterally in an individual. As a result, a debate has developed over how to record and treat bilateral traits in the comparison of skeletal samples. This debate has led to the coalescence of most opinion towards two distinct methodologies. The first method calculates bilateral trait incidence by individual, thus failing to distinguish between unilateral and bilateral expression of a trait. The second method scores bilateral trait incidence by side and then divides these by the total number of sides scored. Those supporting the 'individual' scoring method claim that the 'side' method artificially inflates sample sizes and that it is more realistic to consider the individual as a member of the breeding unit in a biological population (Molto 1983:133). In addition, Korey (1980) observes that bilateral trait incidences increase with developmental age for cranial and infracranial traits. This has led both Korey (1980) and Brasili-Gualandi and Gualdi-Russo (1989) to the conclusion that symmetrically expressed discrete traits (*i.e.*, either both sides present or absent) are predominantly the result of underlying genetic factors, and that unilateral occurrences represent either a transitional phase within individuals or represent random environmental disruptions at some stage during development. Thus, if asymmetrical occurrence is age-regressive and dependent upon environmental stress, sampling by sides would exaggerate the effects of nongenetic factors on trait incidences. Since environmental factors should effect both sides of the body in an equal manner, scoring by individual, regardless of univariate or bivariate manifestation, should provide

accurate estimates of trait incidence. However, even though age dependency may effect the expression of a nonmetric variant, this does not preclude this process from being inherited. Another criticism of the 'side' method results from the widely reported statistical interdependence of nonmetric traits between sides (Saunders 1978:82; McGrath *et al.* 1984). These findings suggest a tendency for discrete traits to appear in the same way on both sides of the body which would lead to the introduction of redundant information and an overestimation of genetic causality on trait expression using the side method (Korey 1980; McGrath *et al.* 1984).

Proponents of the 'side' scoring method claim that it provides the most accurate reflection of nonmetric trait frequencies because it incorporates the maximum amount of nonmetric information from sample populations. If nonmetric trait incidences are not found to vary significantly from side to side, then this method can be used to score poorly preserved skeletal fragments that are difficult to side (Green *et al.* 1979). In fact, proponents of the side method claim that scoring by individual leads to an underestimation of trait incidence estimates in cases of poorly preserved skeletal material. No problem presents itself for bilaterally 'present' or 'absent' expressions since the individual method will detect and score these accurately in one or the other observable sides. However, the positive scoring of unilateral trait incidence begins to approach half of the true population estimate as the availability of both sides for analysis decreases. As opposed to proponents of the 'individual' method, Ossenberg (1981) argues that unilateral expression is due to genetic influences and that as genetic liability for trait expression increases so does the probability of bilateral occurrence. If additive genetic factors account for the propensity to express trait symmetry and asymmetry, then a side count would be more meaningful as a genetic index because it recognizes the increased genetic potential for trait expression in individuals displaying bilateral occurrence (Ossenberg 1981). However, in a study of 13 nonmetric traits in a series of rhesus macaque skeletons with known genetic relationships, genetic influence on trait asymmetry was found to be low even though high positive correlations between sides for trait presence indicated that the genetic basis for expression was the same for both sides (McGrath *et al.* 1984). These findings would tend to support a nongenetic explanation of unilateral trait expression. However, Molto (1983:138-139) argues that in many studies the correlation for side interdependence is unduly inflated since the prevalent manifestation of most traits, *common absence*, artificially weights the statistic towards

perfect side correlation. In his study, Molto (1983:138) demonstrates that a greater percentage of nonmetric traits are unilateral when expressed in an individual. Consideration of this obvious oversight concerning the interpretation of correlation coefficients for side interdependence forwards a strong argument for the 'side' scoring method.

As demonstrated above, the polarization of opinions concerning the side versus individual scoring methods is a result of both theoretical disagreement concerning the primary cause of unilateral trait expression in humans and methodological problems concerning the interpretation and appropriateness of statistical procedures. Most practitioners believe that the expression of symmetry in nonmetric traits is under some degree of genetic control, but that significant levels of environmental modification contribute to this factor of expressivity (Trinkaus 1978; Saunders 1989). Despite this agreement, the utilization of different scoring methods has persisted. The use of different recording methods carries important ramifications for future research since trait incidences derived by different means are incomparable and lead to different measures of sample divergence. For this reason, nonmetric trait incidences using both methods should be reported to ensure the future comparability of data despite which method is chosen for the construction of biological distance coefficients.

Another important aspect of side variability quite distinct from the analysis of side to side trait interdependence is testing for side differences in trait incidence. This analysis is particularly important for the 'side' scoring method since if significantly different trait incidences are recorded between the sides, then the sides should not be pooled for purposes of comparison. In a review of studies conducted on over 20 populations from different parts of the world, Hauser and De Stefano (1989:10) report no evidence of consistent side preference from trait to trait or sample to sample. Although the level of side differences in trait incidence are generally low and minimally affect biological distance calculations, the analysis of side preference in trait expression and their inconsistencies between populations samples should be standard practice in skeletal nonmetric studies.

Age Difference

The existence of significant age variability in nonmetric trait expression has been documented in several human populations (Ossenberg 1969; Corruccini 1974; Saunders 1978; Korey 1980; Molto 1983). Most researchers agree that the main effects of age on trait expression occur during the active growth period and recommend that subadults be excluded from samples in order to remove the biasing effects of these developmental processes (Corruccini 1974; Saunders 1989). Considerable debate still exists as to the effect of adult age changes on nonmetric trait expression. Hauser and De Stefano (1989:9) claim that age may be ignored when dealing with adult material, but not with pre-pubertal material. Studies of age effects by trait category have suggested a trend of age progressiveness for hyperostotic traits and age regressiveness for hypostotic traits (Ossenberg 1969; Saunders 1978; Molto 1983). These processes may be the result of continued periosteal bone growth and generalized bone modification that occur throughout life, contributing to the formation of hyperostotic traits and the obliteration of hypostotic variants (Saunders 1989). Thus, Buikstra (1972, 1976:49) supports a scoring technique that views partially formed hyperostotic traits in younger individuals as complete manifestations because they are both products of the same genotype. In contradiction to the above, Brasili-Gualandi & Gualdi-Rosso (1989) observed no difference in hyperostotic and hypostotic traits in the aging adult, with only a few foraminal traits showing significant age variation. These researchers also report a significant increase in 'unreadable' traits in the 70 years of age and older skeletal subset. The controversy concerning the effects of adult age on nonmetric trait expression is far from resolved. Current findings demonstrate that the effects vary on a trait by trait basis and, likely, from population to population. As compared to the significant changes observed during the active growth period, the effects of adult age changes on nonmetric trait expression appear minor. However, the continued study of age variability will provide important insights into the genetically controlled and environmentally mediated developmental processes involved in their expression (Saunders 1989).

Sex Difference

Since the initial popularity of nonmetric biological distance studies on human populations, many researchers have assumed that sex differences in nonmetric trait

expression are minimal (Berry & Berry 1967; Cosseddu *et al.* 1979). Corruccini (1974) first recognized in a study of skeletons of known sex that the number of traits significantly affected by sex exceeded those that would be expected by chance. Perizonius (1979) criticized these findings on methodological grounds, since the 'side' method was used for scoring bilaterally occurring variants. Increasingly, however, it has become evident that, for certain trait categories, size influence is mediated by sexual dimorphism. Researchers have detected an association between hyperostotic traits and higher male incidence and between hypostotic traits and higher female incidences and propose that this is the result of reduced bone robusticity in females or to their retention of smaller size (Ossenberg 1969; Saunders 1978; Molto 1983). As suggested by Saunders (1989), however, sex differences in trait incidence are not necessarily related to size differences alone, but may also be attributed to different processes of bone growth and different developmental (*i.e.*, hormonal) responses between the sexes. Similar sex-related patterns have not been reported for foraminal traits.

Most researchers agree with the method of separating male and female skeletons in biological distance studies in order to identify the intrapopulational influences of sex on nonmetric trait development. As with age variability, a major problem in the debate over the existence of sexual dimorphism in trait expression is that most results are negative or show little consistency between populations (Brasili-Gualandi and Gualdi-Russo 1989; Hauser & De Stefano 1989). Perizonius (1979) suggests that once the significant intersex traits within a population are identified and excluded, then fragmentary and unsexable skeletons may be included in the analysis thus increasing the sample size. Other methods developed to minimize the effects of intersex variation in nonmetric studies include the omission of one sex from biological distance calculations for sex-associated traits, or keeping the proportions of sexes approximately equal. According to Saunders (1989), all of these solutions run the risk of removing or diluting potentially valuable information concerning intrapopulation heterogeneity. In fact, the careful analysis of sex differences observed through such analyses may provide information about nonrandom gene flow in a population such as may result from prescribed kinship systems and associated residence patterns (Corruccini 1972).

Intertrait Correlation

Given the assumption that minor skeletal variants are controlled by an underlying normally distributed liability for trait expression that is composed of a large number of genetic and nongenetic factors, then correlations between traits should be low (Truslove 1961). This assumption has been considered one of the major advantages of discrete trait analysis since the apparent lack of correlation between traits renders valid the practice of accumulating trait differences on an equally-weighted basis to estimate biological distance (Corruccini 1974). Indeed, given the large number of genetic and nongenetic factors influencing trait development, it is not surprising that many studies have found low levels of correlation between traits (Corruccini 1974). As pointed out by Molto (1985), however, many studies employing adequate sample sizes have had to reject the null hypothesis of trait independence on statistical grounds. As sample sizes increase, intercorrelations between traits are more frequently observed.

Research on the interaction between nonmetric traits in inbred mouse populations have identified certain biologically induced trait inter-associations that are related to alternate expressions of the same underlying variable, common regional effects or common developmental processes (Truslove 1961). In human skeletal populations, a tendency towards the association of either hypostotic or hyperostotic traits has been detected by several researchers (Ossenberg 1969; Buikstra 1976; Korey 1980). In addition, a regional effect that produces higher correlation levels between adjacent versus non-adjacent traits has been suggested as a major determinant of intercorrelation (Hertzog 1968). Experiments with diet have demonstrated that common environmental factors can similarly affect the correlation between nonmetric traits (Saunders 1989). Population differences in the pattern of intertrait correlations have also been reported (Korey 1980). Sjøvold (1977b) concludes that nonmetric traits are correlated for both genetic and environmental reasons. He maintains, however, that for the small sample sizes available to researchers of ancient human populations, the effects of trait intercorrelations will not affect the biological distance statistic to a greater extent than would random fluctuations of independently expressed traits. Saunders (1989) stresses that detection of intertrait association reveals meaningful information about trait etiology that assists in the clarification of genetic or environmental factors that affect skeletal variability within and between human populations.

Molto (1985) suggests that intercorrelations between discontinuous traits are a potential hazard to distance studies since they provide redundant information to the tabulated trait incidences. As a result, large samples should be used, preferably greater than 300 individuals per population, to assure the proper detection and removal of intercorrelated traits before distance analysis. Unfortunately, prehistoric skeletal samples of 300 or more individuals are rarely discovered. In consideration of the above findings, it appears that nonmetric traits deriving from a common fundamental process or situated in the same skeletal region may be associated in their occurrence, but that other variants are largely independent in their expression from one another. When sample sizes permit, the existence of possible intertrait association should be examined when interpreting statistical comparisons between population samples.

2.3 Discussion

Associated with the initial widespread popularity of skeletal nonmetric analysis was the assumption that nonmetric traits, as opposed to metric attributes, "... are highly genetic in nature, vary in frequency even between closely related populations, exhibit constancy under environmental variability, do not vary with age, show no sex differences, show virtually no correlation with one another, and are easily defined and standardized" (Corruccini 1974:425). Although most of these assumptions have been false, the initial belief that burial populations could be aggregated for analysis, maximizing sample sizes, and the ease with which these traits could be scored greatly facilitated their increasing popularity for use in biological distance studies. Since the introduction of skeletal nonmetric analysis, methodological studies have assumed prominence over purely analytical approaches as researchers realize the misconceptions of earlier assumptions (Buikstra *et al.* 1990). This line of research has been crucial for the standardization of methodological aspects of nonmetric trait analysis and for assisting with determinations of the type and proportion of nonmetric variation that is attributable to genetic and nongenetic factors. Regarding this latter point, the analysis of intrapopulational characteristics of nonmetric expression in skeletal samples has been forwarded as a means of identifying and eliminating those traits whose expression are significantly influenced by hormonal, developmental, environmental or physiological factors. The genetic significance of biological distance comparisons is heightened by the

elimination of those nonmetric variants displaying significant side, sex and age differences in their expression.

3.0 OUTLINE OF THE PREHISTORY OF BARABA, WESTERN SIBERIA

In order to understand and interpret the biological differentiation manifest within and between Eneolithic and Developed Bronze Age populations within the Baraba region it is necessary to have an understanding of the prehistory of the area. This is especially important for the present study as cranial samples were selected on the basis of culture-historical attributes as displayed in the mortuary practices and burial inventory at the Sopka-II site. The study of prehistory in Baraba, like all regions of Western Siberia, is intimately linked with the historical development of archaeological research within the former Soviet Union. Among the primary goals of Soviet prehistoric research is the reconstruction of the ethnic origins of present and past populations of the region. The examination of ethnic historical developments is based primarily upon archaeological evidence, although many Soviet scholars value the insights provided by physical anthropology, linguistics and ethnography. Russian archaeologists adhere to the three-stage division of prehistory (*i.e.*, the Stone, Bronze and Iron Ages) and tend to focus upon the processes of diffusion and migration for explaining culture-historical developments. Traditionally, Soviet archaeologists have adhered to the Marxist idea that the productive forces guide the nature and timing of human cultural development (Bulkin *et al.* 1982). Thus, the culture-historical phases are recognized by discrete shifts in technological sophistication that are thought to be determining factors behind the increasing complexity observed in the archaeological record. As a result, the diffusion of microlithic tool technology in the Mesolithic and especially ceramic and metal assemblages during the Neolithic, Eneolithic and Bronze Age have been emphasized in culture-historical reconstructions of the area.

Soviet prehistorians view the biological composition of past and present human populations as reflective of the cultural processes and interactions associated with their unique historical development (Levin 1964). Previous biological distance studies in Russia have favored the analysis of metric attributes and general morphological characteristics of the human skull. The 'biological race' concept is fundamental to the majority of biological distance studies in the former Soviet Union where skeletal groups

are categorized into certain broadly defined, and largely preconceived, 'racial' classifications (*i.e.*, Mongoloid, Europoid, Meditteranoid). The concept of race, or subspecies, in human biology has generally fallen out of favor over the last 50 years in light of recent studies that reveal more biological variation within than between the major human 'races' and the tendency for clinal distributions of biological variation between geographical areas (Brace *et al.* 1993; Kennedy 1995). Nevertheless, the typological approach for classifying ancient human populations continues to dominate physical anthropology in Russia.

This study uses the 'biological population' model and nonmetric cranial analysis to examine the biological consequences of archaeologically-derived hypotheses of cultural interaction and migration for the Baraba region during the Eneolithic and Developed Bronze Age. The results will be compared to interpretations of the 'racial' composition of these culture-historical groups forwarded by Soviet physical anthropologists. Despite the focus of this work on the Eneolithic and Developed Bronze Age, the Late Neolithic is also considered in the following section since it represents a significant stage in the ethnic development of Western Siberian populations (Kosarev 1987:314). The geography and palaeoenvironmental history of Western Siberia is briefly examined in order to provide a context from which to consider the Eneolithic and Developed Bronze Age culture-historical developments. This is followed by a brief outline of the archaeology and skeletal biology for each culture-historical period.

3.1 Natural Environment

Western Siberia is dominated by a vast lowland plain which extends eastward from the Ural mountains until reaching the Yenisei river, and the upland areas of the Central Siberian Plateau (*cf.*, Figure 1.2). To the north, the region extends to the Kara Sea, into which the main waterways, the Ob' and Yenisei rivers, drain from the south. The Altai-Sayan mountain ranges form the southeastern border of the region. To the southwest, towards the Caspian and Aral Seas, Western Siberia forms a geographically indistinct border with the steppe and steppe-desert areas of Kazakhstan in Central Asia. Three major zones of vegetation can be distinguished in Western Siberia: the steppes, the taiga (*i.e.*, the boreal forest) and the northern tundra regions. These vegetational belts extend across the area in vast latitudinally-oriented zones. Separating these broad ecological

zones are ecotones, the forest-steppe in the south and the forest-tundra in the north, which support floral and faunal species typical of the respective bordering regions.

The Baraba region occupies the extensive forest-steppe zone between the Ob' and Irtysh rivers (*cf.*, Figure 1.2). This region is located within the eastern portion of the transitional forest-steppe corridor of Siberian Eurasia. The vegetation of the Barabinsk forest-steppe is characterized by a mixture of coniferous forests, broad-leafed forests and steppe vegetation, the relative proportions of which change on a north to south gradient (Molodin 1985:10). The region is limited to the north by the Vasyugan marshlands and to the south by the Kulunda steppes. The northwestern part of Baraba is connected to the

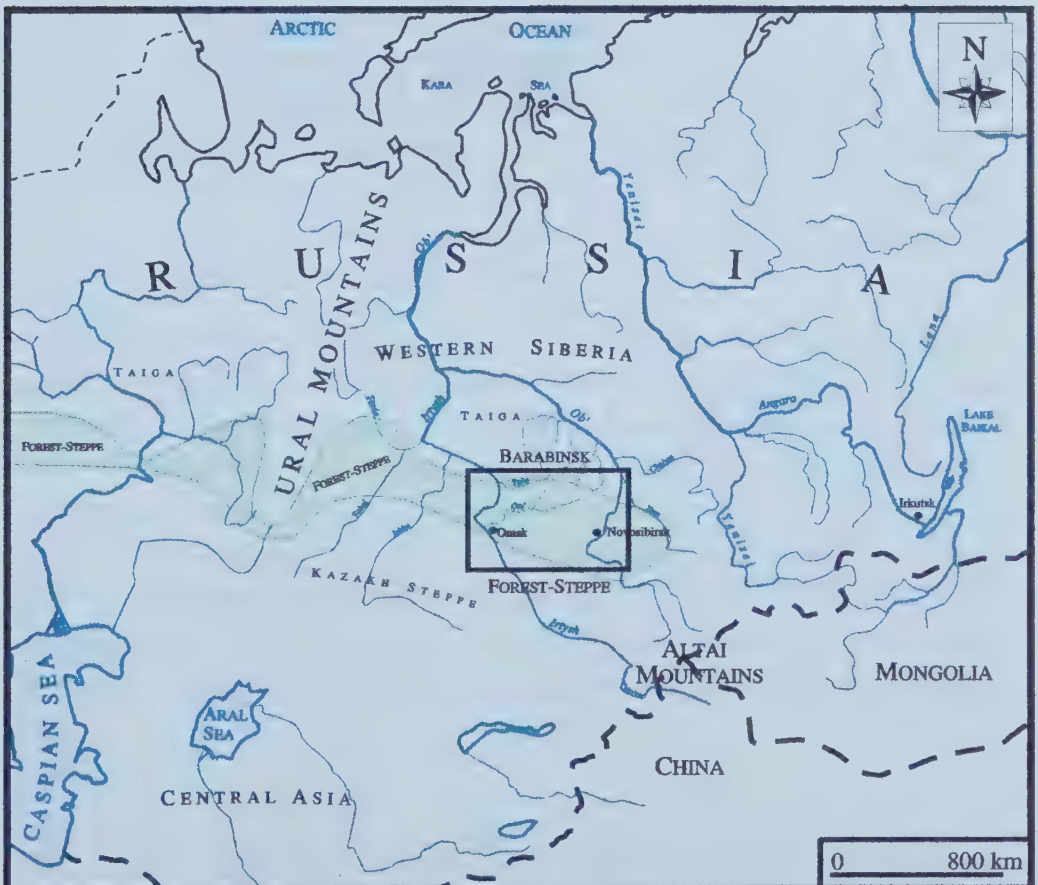
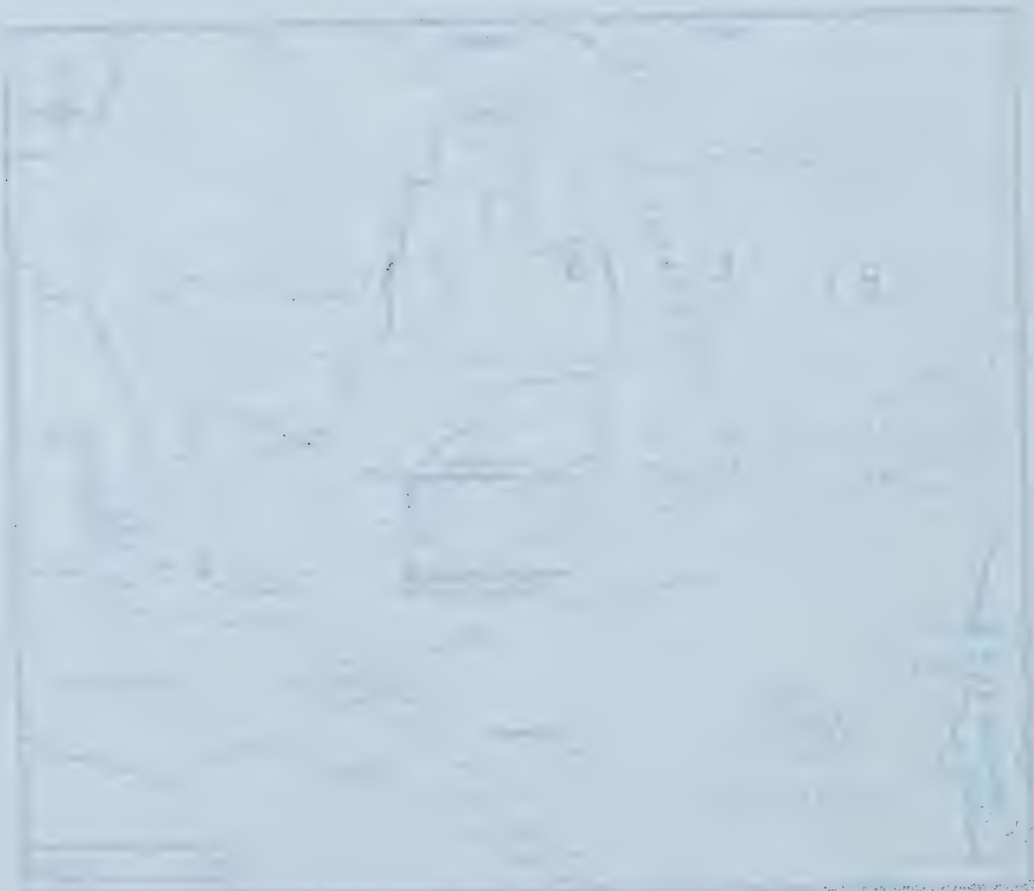


Figure 1.2. Map of Western Siberia displaying portions of Eastern Europe, Central Asia and Eastern Siberia. Note the location of the Barabinsk forest-steppe zone.



Irtysh watershed, with its tributaries, the Tara and Om' rivers, extending eastwardly into the region. The skeletal samples utilized in this study are from archaeological sites located along a 100 km stretch of the Om' river. In the northeastern portion of Baraba, a number of rivers drain northeastwardly into the Ob' river basin. The remaining areas of Baraba are associated with a series of interior lakes and small waterways.

The Baraba region represents a contact zone between populations inhabiting the forested regions to the north and the steppe zone to the south and also between prehistoric communities dominated by Uralian cultural influences to the west and eastern cultural developments of the Ob', Yenisei and Altai regions (Molodin 1985:176). The extensive tributary systems of the Ob' and Irtysh rivers geographically unite the Barabinsk forest-steppe with lands of the northern Arctic region, the Ural mountains, Kazakhstan, the Altai mountains and the Minusinsk basin (Polos'mak *et al.* 1989:8). Furthermore, the flat topography through which these river systems flow allow for easy river travel, which present and past human populations have utilized as an important communication link with distant regions and their inhabitants. Another important corridor for human migration and cultural diffusion is the steppe zone which borders Baraba to the south and extends uninterrupted for several thousand kilometres across the Eurasian landmass (Masson and Taylor 1989).

Climatic shifts have been typical for Western Siberia during the Holocene and appear to have influenced cultural developments during the Eneolithic and Developed Bronze Age. A modified version of the Blytt-Sernander paradigm has been adopted by Russian prehistorians as the chronological and paleogeographical standard for the Holocene in Siberia[2]. The palaeoenvironmental record for the region reveals an alternation between stages of relative ecological stability and periods of rapid change. Three major vegetational transitions occurred in the region during the Holocene that complete a cycle from cold-tolerant to warm-adapted and then back to cold-tolerant vegetational species (Khotinskiy 1984). These periods of rapid ecological change are

[2] The Blytt-Sernander paradigm is a postglacial geochronological scheme initially developed during the 19th century in Scandinavia. Four periods were initially recorded: the Boreal, Atlantic, Subboreal and Subatlantic. Faegri (1981) provides a thorough analysis of the historical development of this geochronological scheme.

associated with the sudden onset of extremely dry conditions correlated with four major regressions of the Caspian Sea (Matyushin 1986).

The environmental shifts associated with the Atlantic and Subboreal periods are directly relevant to cultural developments of the Late Neolithic, Eneolithic and Developed Bronze Age in Western Siberia (*cf.*, Figure 1.3). The first half of the Atlantic period, until approximately 7,500 BP encompasses the final stages of the first Holocene climatic transformation associated with the transition from treeless landscapes of the late glacial to the period of rapid reforestation of cold-tolerant vegetation during the early postglacial period and the subsequent entrenchment of the steppe, taiga and tundra latitudinal zones (Khotinskiy 1984). The second major climatic transition occurred during the second half of the Atlantic period, beginning around 7,500 BP, when the climate became warmer and wetter. This ecological transition led to increasing differentiation within the vegetational zones that included the colonization of warm-adapted species, the expansion of the forest zones to the north and south, and the stabilization of the forest-steppe boundary to approximately its present position (Khotinskiy 1984). It is postulated that the entire region received double the precipitation it does today (Khotinskiy 1984). The third major Holocene climatic transition is represented by the vegetation changes associated with the onset of the cool, dry and continental climate of the Subboreal period that began at approximately 4,600 BP. Khotinskiy (1984) postulates that this gradual transition is associated with two cool intervals occurring around 6,400 and 4,900 BP during the Late Atlantic period. These cool phases correspond closely to major regressions of the Caspian Sea: The Jilaldin regression (44.5 metres below present sea level) occurred between approximately 6,500 and 6,000 BP and the Makhachkalinsk regression (40.5 metres below present sea level) began by about 5,000 BP (Matyushin 1986). The increasing aridity represented by the Makhachkalinsk regression continued into the Middle Subboreal period until the middle of the 2nd millennium BC. The forest-steppe border did not undergo any appreciable shifts during the Subboreal, but it is assumed that the area experienced increasing aridity (Khotinskiy 1984). The remainder of the Subboreal period and the following Subatlantic phase represent the continued transition to colder climates that resulted in the reentrenchment of cold-tolerant forest types typical of Western Siberia during the present day.

3.2 The Late Neolithic

The Neolithic in Western Siberia does not necessarily equate with the adoption of food producing subsistence strategies. The term 'Neolithic' among Russian scholars carries different meaning depending upon the geographical area being described. In the area between the Ural mountains and the Yenisei river, two main regions have been identified. The first is the forest-steppes and foothills of the Southern Urals which was marked by the appearance of a food producing economy during the Early Neolithic (Dergachev 1989; Matyushin 1986). The Early Neolithic assemblages of domesticated fauna contain horse, cattle, sheep and goat remains and the absence of pigs, maintaining close similarities to the developed food producing economies of the Circum-Caspian region and southern areas of Central Asia (Matyushin 1986). An examination of Neolithic and Eneolithic sites of the Southern Urals has led Matyushin (1986) to suggest the possibility that horse breeding originated here. The extensive region between the Tobol and Yenisei rivers defines the second region. Here the Neolithic boundary is determined by the first appearance of ceramics, improved working tools and an increasing reliance on fishing within the frameworks of a foraging society (Dolukhanov & Khotinskiy 1984). For the Neolithic in both areas, the most important introduction of material culture for the purpose of culture-historical interpretation was the spread of ceramic technology, representing one of the most variable elements in northern Eurasian cultural assemblages (Gimbutas 1958).

The cultural contacts of Southern Uralian populations with areas demonstrating early plant and animal domestication appear to have enabled them to cope more effectively with the marked ecological changes of the early Holocene. As a result, cultural development and population growth continued uninterrupted in this region throughout the early Holocene leading to the dominant influence of Uralian material culture across vast regions of Western Siberia during the Neolithic (Kosarev 1987:314). In fact, the cultural sequence for most regions in Northern Eurasia were originally developed on the basis of archaeological sites of the Ural mountain region (Gimbutas 1958). In the region between the Tobol and Yenisei rivers, the ecological instability associated with early Holocene climatic warming trends is thought to have resulted in a major population reduction by the end of the Mesolithic and Early Neolithic (Matyushin 1986). This is

supported by the paucity of Early and Developed Neolithic sites for the Kazakhstan uplands, the Ob' basin and the Irtysh river regions, including the Barabinsk forest-steppe.

The Early and Developed Neolithic of the Trans-Urals (*i.e.,* east of the Ural mountains) and southern portions of Western Siberia is characterized by a geographically uniform culture identified by the widespread diffusion of ceramic assemblages displaying elongated dimensions, round or pointed bottoms, and 'incision' or 'retreating punctuation' (*i.e.,* otstupaiushche-nakol'chataia keramika) ornamentation (*cf., e.g.,* Polos'mak *et al.* 1989:18). This form of ceramic ornamentation is commonly referred to as 'stab-and-drag' by western archaeologists. This early ceramic technology in conjunction with geometric microlithic artifacts are thought to have been introduced to the Ural region at an early stage of the Neolithic by the Keltiminar culture of Central Asia (Bobrov 1988; Kosarev 1987:315; Michael 1992; Molodin 1977:17). Until recent times, archaeological sites of the Early and Developed Neolithic were virtually unknown for the Baraba region (Molodin 1977:30). The recent discovery of Neolithic burials at the Protoka and Sopka-II sites in the Baraba region have yielded similar pottery assemblages with close analogies to the Trans-Uralian 'retreating punctuation' ceramic tradition (Polos'mak *et al.* 1989:20). This confirms Molodin's (1977:17, 32-33) opinion that the Middle Irtysh region was affiliated with this homogenous Early and Developed Neolithic culture-historical province.

The widespread culture-historical uniformity characteristic of the Early and Developed Neolithic was disrupted with the introduction of new forms of ceramic ornamentation during the Late Neolithic. The relative distribution of these distinct ceramic traditions are thought by Russian scholars to correspond to the boundaries of newly developing ethnocultural communities (Bobrov 1988; Kosarev 1987:314). The process of cultural differentiation during the Late Neolithic has been attributed to human migrations (Molodin 1977:33) and also to rising population densities and the development of increasingly complex economic strategies as the landscape became more variegated during the warm Atlantic period (Dolukhanov & Khotinskiy 1984). Three Late Neolithic cultural complexes have been identified on the basis of pottery and stone tool typology extending from the Ural region to the Ob' basin and dating to the latter half of the 4th and early 3rd millennium BC (*cf.,* Figure 1.3): the Eastern Uralian culture, the Middle Irtysh culture and the Upper Ob'ian culture.

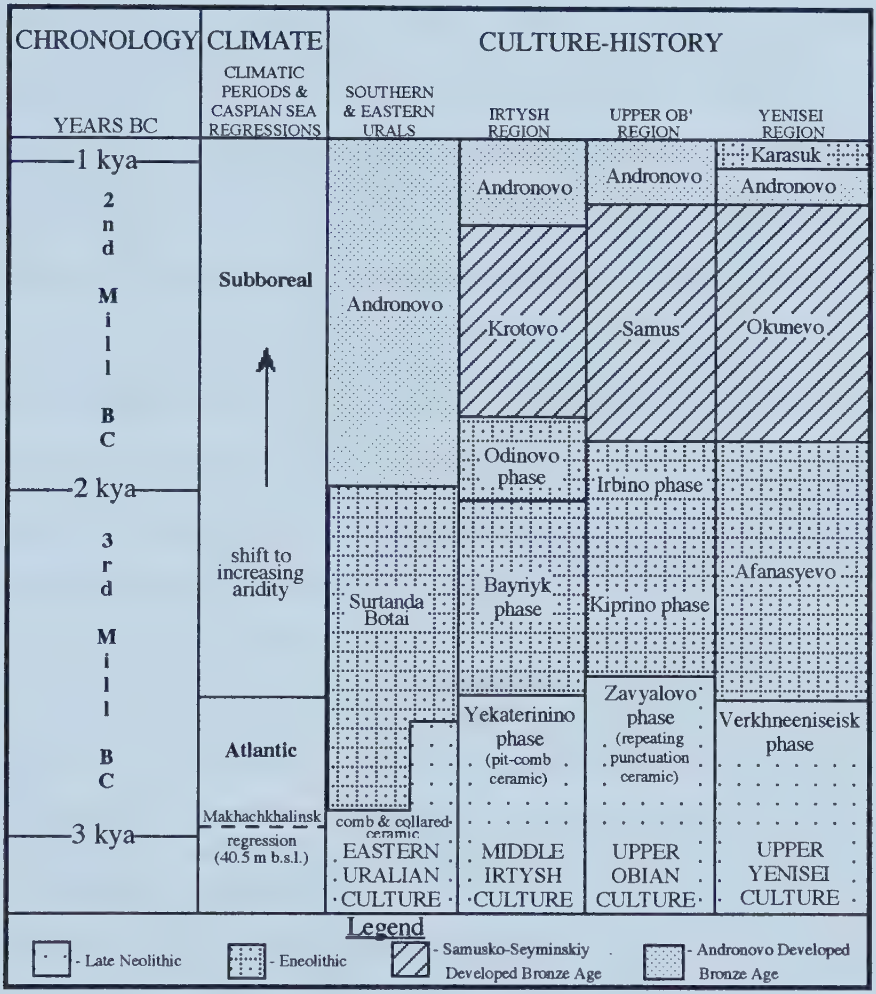


Figure 1.3 The culture-historical sequence and palaeoenvironmental history of the Late Neolithic, Eneolithic and Developed Bronze Age of Western Siberia (adapted from Kosarev 1987 and Molodin 1977, 1985).

The southern forest-steppe communities of the Eastern Uralian culture maintained the pastoralist practices introduced during the Early Neolithic. A foraging economy was retained to the north in the taigan zones of the Eastern Urals. The former widespread distribution of the 'retreating punctuation' ornamentation is interrupted by the appearance of the 'comb' (*i.e.*, grebenchataia keramika) ornamental tradition in the Southern and Eastern Ural regions (Bobrov 1988). The 'comb' ornamentation of the Southern Urals displays similarity to vessels of the Volga and Kama regions of Eastern

Europe which has led Kosarev (1987:314) to conclude that the Pre- and Trans-Ural regions represent a single expanse of ethnically related cultures during the Late Neolithic. Both Okladnikov (1964) and Kosarev (1987:314) regard this cultural-ethnic community, centered in the Trans-Ural region, as the ancestors of present-day Ugrian populations, bordering to the west proto-Finnic groups of Eastern Europe and to the south proto-Indo-European populations of Central Asia. At the onset of the Late Neolithic period, the production of collared ceramics, which had hitherto been confined to the northern shores of the Caspian Sea basin, was also introduced to the Southern Ural region, and distributed among the predominant assemblages of round-bottomed 'comb' ware (Matyushin 1986). This change in ceramic style suggests the occurrence of a northward shift of populations from the Circum-Caspian region. Matyushin (1986) notes a simultaneous shift in the composition of domestic fauna associated with the introduction of collared ceramics to the Southern Urals: The percentage of horse bones drops dramatically while the remains of cattle increase in frequency.

The process of disintegration in terms of the appearance of regionally distinct culture-historical entities is vividly demonstrated at the onset of the Late Neolithic in the Barabinsk forest-steppes where elements of the 'pit-comb' (*i.e.*, grebenchato-yamochnaia keramika; *cf. e.g.*, Okladnikov & Molodin 1978:20) ornamental tradition began to replace the earlier 'repeating punctuation' ornamentation (Molodin 1977:33-34; Okladnikov & Molodin 1978). The distribution of this ceramic tradition marks the development of the Yekaterinino phase of the Middle Irtysh culture during the Late Neolithic and its dissemination to the forest-steppe and southern taigan zones of the Ishim and Irtysh river regions (Bobrov 1988; Kosarev 1987:315; Molodin 1977:31). The form and ornamentation of this ceramic tradition displays ties with ceramic assemblages of the L'yalovo culture inhabiting the Central Volga region of Eastern Europe during the Neolithic (Polos'mak *et al.* 1989:91). It is widely believed among Russian scholars that the introduction of the 'pit-comb' ceramic tradition is tied with the migration of L'yalovo tribes to central regions of Western Siberia at the end of the Neolithic on the boundary of the fourth and third millennia BC (Kosarev 1987:315; Molodin 1985:26-27,33-37; Okladnikov & Molodin 1978). The simultaneous appearance of 'pit-comb' ceramic assemblages in the lower Ob' region is thought to trace the migration of this population across the Ural mountains and then southward through the taigan zones along the Ob' and Irtysh basins to the forest-steppe zone (Molodin 1977:33-34). During this time, the

Early and Developed Neolithic communities of the Baraba region, on the basis of the distribution of 'repeating punctuation' ceramics, were displaced to the eastern forest-steppes between the Ob' and Yenisei river, including areas occupied by the Upper Ob'ian culture (Okladnikov & Molodin 1978). In this regard, the upper and middle portions of the Ob' region represent a refuge for the Early and Developed Neolithic cultural traditions that were displaced from most areas of Western Siberia at the onset of the Late Neolithic (Bobrov 1988; Kosarev 1987:315).

Russian physical anthropologists report that Neolithic populations of the Baraba region display primarily 'Mongoloid' physical traits but with significant admixture of 'Europoid' or 'Caucasoid' racial elements (Polos'mak *et al.* 1989:79). As stated by Chernetsov and Moszynska (1974:61):

> "The ancient populations to the north of the forest-steppes were ethnically unified, associated with the Mongoloid element which, according to physical anthropological data, were distributed widely in the Cis-Baikal region and to the west of it in the taiga zone across the Urals to the White Sea".

Barabinsk Neolithic skulls are thought to resemble the craniological types characteristic of the Western Pre-Baltic, Karelian and the Ural Mountain regions (Polos'mak *et al.* 1989:78, 92). Dremov (1980:44; as reported in Haeussler & Turner 1992) reports the existence of similar Neolithic populations in the Ob' region and suggests that this admixture resulted from episodic movements of European Neolithic populations into Western Siberia where the inhabitants already possessed significant 'Mongoloid' physical traits. In addition, Matyushin (1986) reports the long term migrations of 'Caucasoid' populations from the southern shores of the Caspian Sea to the Southern Ural region and the subsequent dispersal of these groups into the northern taigan zones of Eastern Europe, the Middle and Northern Urals, and eastwardly across the southern portions of Western Siberia (Matyushin 1986). These migrations may have begun as early as the Mesolithic and continued throughout the Neolithic. The long process of admixture between 'Mongoloid' populations to the north and east and 'Europoid' populations to the south and west is thought to have been intensified in the forest-steppe zones of Western Siberia that lay on the boundary of these proposed 'racial' complexes although the relative proportion of the 'Mongoloid' physical appearance increases from the west to the east across this physiographic region (Alexeev 1979; Levin 1964). The cultural and economic developments witnessed during the Neolithic of the Barabinsk

forest-steppe is connected mainly with cultural contacts or migrations from the Trans-Ural region and the northwestern portions of Western Siberia. Bobrov (1988) believes that these developments in the forest-steppes of Western Siberia occurred within the framework of foraging groups that developed out of local Mesolithic origins. The biological result of these cultural processes in Baraba are similar to those occurring, to varying degrees, across the entire region of Western Siberia: the admixture of 'Europoid' or 'Caucasoid' physical traits within the autochthonous 'Mongoloid' populations of the region.

3.3 The Eneolithic and Early Bronze Age

The Eneolithic represents a complex history of population movements and cultural developments occurring in Western Siberia during the 3rd millennium BC. It is thought that a demographic explosion occurred in Western Siberia during the Eneolithic with increasing populations inhabiting the steppe, forest-steppe and Altai mountain regions that earlier were poorly populated (Kiryushin 1994). The Eneolithic in Western Siberia represents a continuation of the cultural disintegrations observed in the Late Neolithic. The dynamic forces behind the shift to small and distinctive culture-historical entities is thought to be associated with the transition to a drier climatic regime at the onset of the Subboreal period and the northward penetration of food producing and metal-using communities into the domain of foraging groups.

The Eneolithic period is marked by the widespread diffusion of copper and early bronze tools to Western Siberia. It has been suggested that the appearance of metal artifacts in Western Siberia is the result of intensified contact between Southern Uralian populations and the metal-using Keltiminar groups of Central Asia during the 3rd millennium BC (Matyushin 1986). The introduction of metal led to the development of improved tools which stimulated increasing trade among populations of Western Siberia for both the implements and the copper and tin ores needed for their production. As a result of these early contacts, most of the ancient populations of Western Siberia had switched from stone to metal technology by the latter half of the 3rd millennium BC and are considered to belong to the Early Bronze Age (Bobrov 1988).

The Eneolithic and Early Bronze Age are also characterized by the widespread introduction of pastoralism to the steppe and forest-steppe zones of Western Siberia

(Bobrov 1988). This process appears to have been stimulated by the 1,000 year transition from the warm and wet Atlantic period to the dry and cool Subboreal period (Michael 1992). This climatic transition appears to have stimulated human populations to either adopt economic strategies better adapted to the new conditions or to migrate to more favorable regions (Dolukhanov and Khotinskiy 1984). Pastoralist and foraging economies coexisted in the forest-steppes of Western Siberia during the Eneolithic and pastoralist practices were selectively adopted by local groups within the framework of well-established hunting and gathering economies. As a result, it is likely that the spread of pastoralism to the forest-steppes was accompanied by increasing population movements as local groups sought out the most favorable environments for both old and new subsistence activities.

Beginning in the Eneolithic, the steppes of Western Siberia developed from a contact zone to an independent center of cultural development (Bobrov 1988). Dergachev (1989) observes the propensity for most Neolithic and early Eneolithic pastoralist sites to be located within the northernmost steppe and forest-steppe regions of Western Siberia. This propensity suggests that the local climate and mixed forest and meadow landscapes of the forest-steppe were most favorable for the introduction of early food producing adaptations in Western Siberia. In addition, the increasing aridity associated with the onset of the Makhachkalinsk regression of the Caspian Sea by about 5,000 BP resulted in the widespread shift to a nomadic mode of existence by Eneolithic stock-breeding populations (Matyushin 1986). The adoption of nomadic or semi-nomadic pastoralism, in conjunction with the further development of horse-breeding and technological innovations such as wheeled transportation and the stirrup, allowed populations for the first time to intensively occupy the Eurasian steppes (Dolukhanov & Khotinskiy 1984; Masson & Taylor 1989). The widespread shift to a transhumant lifestyle transformed the Eurasian steppes into a natural highway for human migration and the diffusion of material culture. The increasing development of nomadic pastoralism and transhumance reduced differences in language and material culture in the steppes and facilitated the formation of more extensive territorial communities (Chernetsov and Moszynska 1974:73). The transition to a stock-breeding transhumant lifestyle in the Eurasian steppes is considered to be as important an event in human history as the development of urban centers in other world regions (Masson & Taylor 1989).

The Surtanda-Botai and Afanasyevo Eneolithic cultures represent the earliest pastoralist cultural communities to intensively occupy the Asiatic steppe and forest-steppe zones of southern Siberia. These prehistoric cultural developments occurred at the beginning of the 3rd millennium BC. The form of economy practiced by both cultural complexes was similar displaying varying degrees of sheep, cattle and horse domestication (Matyushin 1986). The Surtanda-Botai culture developed in the Southern Urals and Western Kazakhstan and displays the initial shift to nomadic pastoralism in Western Siberia (Matyushin 1986). Late Neolithic pastoralist settlements in the same region were abandoned with the increasing residential mobility associated with the adoption of a nomadic lifestyle (Matyushin 1986). Flat-bottomed, corded-ware pottery typical of the Surtanda-Botai culture has been discovered in northern Kazakhstan, the northern forest zone of the Urals and eastwardly into Western Siberia up to the Irtysh river. An eastward variant of this culture in the forest-steppe Botai region displays a specialized economy based upon intensive horse-breeding (Matyushin 1986). At approximately the same time, the Afanasyevo culture appeared in the Altai and Yenisei regions replacing the local Neolithic populations of the area and introducing flat-bottomed, corded-ware ceramics, kurgan burial practices and biological characteristics typical of Surtanda-Botai groups to the west (Vasil'ev & Semenov 1993). These related cultural traditions were also the initial populations to engage in ore mining and metallurgy in Western Siberia (Khlobystina 1972; Matyushin 1986).

The transition to the Eneolithic in the Barabinsk forest-steppe occurred later during the latter half of the 3rd millennium BC and was heavily influenced by the Afanasyevo and Surtanda-Botai cultural communities to the south. The Bayriyk phase of the Eneolithic is characterized by the continued development of the 'pit-comb' ceramic tradition, introduced to the region during the Yekaterinino phase of the Middle Irtysh Neolithic (Okladnikov & Molodin 1978). The similarities that tie this Eneolithic culture to its Neolithic predecessor include the prevalence of round and sharp bottomed pots and the retention of archaic 'retreating punctuation' ornamental motifs within a developed 'pit-comb' tradition (Molodin 1985:26-27). Molodin (1994) suggests that these features of the Bayriyk material culture forward a strong argument for cultural continuity in the Baraba region over the Late Neolithic and Eneolithic. An introduced aspect of material culture during the Bayriyk phase is the appearance of flat-bottomed pottery (Molodin 1985:27). In addition, the artifact assemblage of the Bayriyk culture demonstrates the

introduction of early copper and bronze implements which coexisted with a rich blade inventory typical of the Neolithic (Molodin 1994). The developed stone tool inventory and the faunal materials excavated from sites of the Bayriyk stage indicate the retention of a foraging economy in the Barabinsk forest-steppe throughout this time (Molodin 1994).

The Odinovo phase of the Early Metal period succeeds the Bayriyk culture within the Barabinsk forest-steppe and represents the final phase of development of the 'pit-comb' culture-historical community within the region. During the first half of the second millennium BC, the Odinovo culture occupied the vast forest-steppe region between the Ishim and Irtysh rivers. Typological similarities between the 'pit-comb' ornamental tradition of the Odinovo and Bayriyk sites suggest cultural continuity for these Eneolithic populations in the Baraba region (Molodin 1985:34). Distinguishing features of the Odinovo phase include the increasing frequency of flat-bottomed ceramics, the continued development of copper and bronze metallurgy, and the decreasing quantity and quality of the stone tool inventory (Molodin 1985:34). However, the greatest distinguishing characteristic of the Odinovo phase is the development of a food producing economy based on cattle breeding. The processes of cultural change associated with the Bayriyk and Odinovo phases of the Baraba Eneolithic are characteristic of earlier developments in the Surtanda-Botai and Afanasyevo cultural communities that inhabited the southern forest-steppe and steppe regions of Western Siberia at the onset of the Eneolithic.

The spread of nomadic pastoralist groups across southern portions of Western Siberia during the Eneolithic resulted in the juxtaposition of two cultural traditions in the forest-steppe zone that differed both in ethnicity and economic structure (Okladnikov 1964). Here existed foraging populations of the taiga and northern forest-steppe zones that developed out of local Neolithic origins. These populations displayed mainly 'Mongoloid' physical characteristics. Also present in the region were prehistoric populations displaying 'Europoid' physical traits who occupied the steppe and southern forest-steppe regions during the Eneolithic and Bronze Age (Haeussler & Turner 1992). According to Okladnikov (1964), the similar physical appearance of the latter group of steppe tribes is explainable only by the occurrence of intensive human migrations from the west to the east during this time. These populations displayed varying degrees of 'Mongoloid' physical traits over time depending upon their proximity to the taigan zone

where the majority of genetic mixing is thought to have occurred. The intensification of southern cultural influences in the Baraba region during the Eneolithic is suggested by the appearance of metal, flat-bottomed pottery and food producing economies. Despite the possibility of simultaneous population movements into the region, the Eneolithic and Samusko-Seyminskiy Developed Bronze Age populations of Baraba display primarily 'Mongoloid' physical traits, although with varying amounts of 'Europoid' admixture (Molodin & Chikisheva 1988). In addition to this, the retention of archaic forms of ceramic ornamentation and mortuary ritual suggest that Eneolithic cultural developments in the Baraba region were not associated with simultaneous and intensive migrations of southern 'Caucasoid' tribes. As a result, Eneolithic cultural developments in the Baraba region are believed to have occurred among populations displaying ancestral relationships with autochthonous Late Neolithic populations of the region.

3.4 The Developed Bronze Age

Two distinct culture-historical developments occurred during the Developed Bronze Age in the Baraba region: the Samusko-Seyminskiy and the Andronovo epochs. These cultural developments spanned the 2nd millennium BC. The Samusko-Seyminskiy epoch is the initial phase of the Developed Bronze Age in the Baraba region and represents a period of cultural consolidation associated with the complete entrenchment of metal technology, the development of local centers of bronze metallurgy, and further establishment of the food producing economy (Bobrov 1988). This period is associated with the appearance of a series of related Samusko-Seyminskiy communities in the forest-steppes and southern taiga of Western Siberia (Kosarev 1987:274; Molodin 1977:67). The continued development of pastoralism and the introduction of rudimentary agriculture gradually led to economic differentiation in the forest-steppes that resulted in the coexistence of sedentary communities of early agriculturalists and groups where transhumant cattle breeding predominated (Chernetsov and Moszynska 1974:72).

The parallel emergence of the Andronovo culture has important implications for the second phase of the Developed Bronze Age in the Baraba region. The Andronovo culture developed out of the Eneolithic Surtanda-Botai populations that inhabited the region between the southern Urals and the Irtysh river (Dergachev 1989). The appearance of the Andronovo culture was associated with the development of the Ural

and Eastern Kazakhstan centers of ancient metallurgy which, like in the Samusko-Seyminskiy cultural communities, set the forest-steppe and steppe tribes technologically ahead of their neighbors (Chernetsov and Moszynska 1974:72). The sophisticated technological achievements of the Andronovo culture and the parallel intensification of a complex farming economy based upon sheep-breeding completely opened the steppes for human occupation (Dergachev 1989). By the end of the Developed Bronze Age around the 12th century BC, the Andronovo culture had extended as far east as the Yenisei river, as far north as the taigan zones of Western Siberia and as far south as the desert oases of Central Asia (Dergachev 1989). The displacement of Samusko-Seyminskiy cultural groups and the subsequent cultural consolidation associated with the widespread expansion of the Andronovo culture, identified through the widespread diffusion of flat-bottomed Andronovo pottery and characteristic metal tools, reestablished the broad cultural uniformities evident in Western Siberia during the Early and Developed Neolithic (Chard 1958).

The onset of the Samusko-Seyminskiy epoch in the Baraba region is tied with the appearance of the Krotovo culture during the first half of the 2nd millennium BC (Molodin 1977:55). On the basis of ceramic and bronze typology, the Krotovo culture has been affiliated with a series of related cultural traditions of Samusko-Seyminskiy type including the Okunevo of the Yenisei region and several variants of the Samus culture that inhabited areas of the Ishim, Irtysh and Ob' watersheds (Kosarev 1987:272; Molodin 1995b). The origins of the Samusko-Seyminskiy cultural tradition are considered to be related to the development of the Samus culture in the eastern forested regions of the Upper Ob' at the onset of the 2nd millennium BC (Okladnikov and Molodin 1978). The Samus culture is recognized on the basis of varied ceramic forms with distinctive ornamentation and the development of the Turbinsko-Seyminskiy center of bronze metallurgy based upon local ore deposits of the Altai region (Kosarev 1987:316). The Samus pottery retains archaic features of the 'repeating punctuation' ornamental tradition which has led several researchers to suggest that it developed on the basis of local Eneolithic cultures of the Upper Ob' region (Molodin 1994; Okladnikov & Molodin 1978). The Samus populations retained a foraging mode of existence similar to economic strategies practiced earlier during the Eneolithic (Okladnikov & Molodin 1978). Elements of early producing economies were more typical of forest-steppe

cultural communities of Western Siberia during the Samusko-Seyminskiy Developed Bronze Age (Kosarev 1987:272).

The Krotovo culture represents one of these early food producing communities that entered into the circle of forest and forest-steppe cultures of the Samus and Okunevo types during the middle of the 2nd millennium BC (Molodin 1977:55; Okladnikov & Molodin 1978). The exact origins of the Krotovo culture in the Upper Ob' region is still disputed but these groups gradually spread westward into Baraba. This is demonstrated at the multi-stratified Vengerovo-III site in Central Baraba where cultural levels containing Eneolithic 'pit-comb' pottery are separated from an upper stratum belonging to the Krotovo culture (Molodin 1995a). The boundary of the Krotovo cultural community was initially identified on the basis of distinctive flat-bottomed ceramics characterized by 'retreating punctuation', 'retreating comb' and 'spindle / relief roller ' (*i.e.*, valikovaia keramika) ornamentation (Molodin 1995a). The stone inventory of the Krotovo culture is not remarkable in the typological sense, representing the continued degradation of this technological tradition in the Baraba region from the Odinovo phase of the late Eneolithic (Molodin 1995a). The Krotovo cultural community produced bronze artifacts typical of the Turbinsko-Seyminskiy center of bronze metallurgy to the east and continued to develop the pastoralist horse, cattle and sheep breeding economy introduced earlier during the Eneolithic (Molodin 1995a). However, the faunal remains excavated from Krotovo sites demonstrate the continued reliance on hunting. Like the Neolithic and Eneolithic, the burial ritual of the Krotovo culture is dominated by single pit inhumations with individuals placed in the extended position. However, the later stages of the Krotovo culture are associated with the increasing appearance of bronze implements, elements of ceramic ornamentation (*i.e.*, hatched triangles along rim, pot-shaped forms) and kurgan burial customs typical of the Andronovo cultural tradition (Molodin 1977:68; Molodin 1995a; Okladnikov and Molodin 1978). The increasing development of contacts with western and southwestern cultural influences foreshadows the following phase of the Developed Bronze Age in the Baraba region when the Krotovo culture is completely replaced by the Andronovo cultural tradition.

The onset of the Andronovo epoch in the Baraba region dates to the 13th century BC when Andronovo populations began expanding eastwardly to areas inhabited by the Samus and Krotovo cultures, settling largely in the southern taigan and forest-steppe

zones (Kosarev 1987:276; Molodin 1995b). However, it is likely that this contact developed many centuries earlier during the late phases of the Krotovo culture. Molodin (1995b) observes stratigraphic evidence for this transition in the Preobrazhenka-III and Sopka-II sites in Central Baraba where Krotovo burials and habitation sites are found below later Andronovo occupations. Okladnikov and Molodin (1978) suggest that local tribes of the Krotovo, Samus and Okunevo cultures were either forced out of the forest-steppe zone or assimilated by incoming Andronovo populations. The Andronovo developed a mixed herding and farming subsistence economy that depended little on hunting and fishing (Kosarev 1987:278). Farming and the herding of cattle, sheep, goats and the horse predominated in the forest-steppe regions. In the steppes, semi-desert and mountainous regions, transhumant sheep pastoralism prevailed. The importance of farming in relation to pastoralism for Andronovo populations depended on specific environmental conditions and differed both within and between vegetational zones (Dergachev 1989).

The first intensive migration of 'Europoid' populations to the forest-steppe Ob'-Irtysh is believed to have occurred during the late stages of the Krotovo culture and is associated with the advance of Andronovo populations from the Kazakhstan steppes at the onset of the second phase of the Developed Bronze Age (Molodin & Chikisheva 1988). The formation of the Andronovo physical type occurred in Kazakhstan and the Altai territory and only later penetrated eastwardly to the Yenisei region (Kiryushin 1994). Andronovo skeletal assemblages discovered in the Yenisei region, Western Kazakhstan and Western Siberia display similar characteristics that indicate the extensive habitation of the steppe and southern forest-steppe regions of Western Siberia by 'Europoid' populations (Okladnikov 1964). The biological characteristics of the Krotovo culture of the Samusko-Seyminskiy epoch are still poorly understood but display considerable biological heterogeneity with the appearance of 'Europoid' and mixed 'Europoid-Mongoloid' crania among the predominantly 'Mongoloid' physical type (Dremov 1984: as in Molodin & Chikisheva 1988:170). That this process of biological contact continued into the Andronovo epoch is supported by the manifest heterogeneity of Andronovo skeletal assemblages from the Preobrazhenka-III burial ground in Central Baraba. Typical 'Mongoloid' crania with slight 'Europoid' admixture, characteristic of previous Samusko-Seyminskiy times, were readily distinguished from the 'Caucasoid' crania (Molodin & Chikisheva 1988: 170). The physical evidence supports Toth's

(1981:195) assertion that the process of gracilization of Mongoloid populations inhabiting the northern forest steppe zone was autochthonous and stimulated by the arrival of Caucasoid groups to the region. The heterogeneous nature of the physical types represented in skeletal series of the Baraba region suggest the recent development of contacts between these populations during the Developed Bronze Age.

3.5 Discussion

Russian prehistorians interpret the cultural developments occurring in Baraba, and the entire region of Western Siberia, from the Neolithic to the Developed Bronze Age as resulting from a unique sequence of historical events that included the domestication of the horse, the development of wheeled transportation, the adoption of nomadic and semi-nomadic pastoralism and the development of local centers of metallurgical production. Within this unique historical trajectory it is possible to delineate several general trends. Firstly, prehistoric developments in the region were mainly influenced by cultural diffusions and population migrations from Eastern Europe, the Ural mountains and Central Asia rather than from Eastern Siberia (Kosarev 1987:314). Secondly, this prehistoric period is characterized by the transition from a relatively homogenous culture-historical entity during the Early and Developed Neolithic to the appearance of distinct cultural traditions in the Late Neolithic and Eneolithic and eventually to the vast cultural consolidations associated with the Developed Bronze Age. Thirdly, significant economic transitions occurred during this time from a foraging economy to the nomadic and semi-nomadic pastoralism introduced during the Eneolithic, and eventually to the mixed agricultural/pastoral economies characteristic of Developed Bronze Age communities. Associated with these economic transitions was the increasing habitation of the steppe region.

The relevance of the presented culture-historical interpretations for determining ethnic affinity of ancient Barabinsk populations is quite small because these studies define patterns of dissemination of cultural information and not genetic flow. Bogucki (1987) has argued that the stylistic variation in material culture represents patterns of information flow from which patterns of social interaction can be inferred. However, the extent to which these interactions result in interbreeding between different cultural communities is impossible to determine without the examination of skeletal remains associated with the respective archaeological cultures. Unfortunately, current

craniometric interpretations of Eneolithic and Developed Bronze Age skeletal assemblages of the Baraba region present broadly-defined 'racial' categorizations that assist little in determining the micro-evolutionary processes responsible for the genetic constitution and variation within and between these past human populations.

As a result of the inherent limitations of culture-historical interpretations for determining biological affinity, it has been attempted to compare this record of human culture change with the climatic and vegetational history of Western Siberia. This process assists with interpretation of prehistoric sociocultural developments and hypothesized migrational events because, at least for foraging groups, the natural environment is an important factor in the process of culture change. Environmental perspectives alone, however, simplify the complex adaptiveness of human culture and become less effective for explaining cultural change after the onset of the Metal Age in Western Siberia, when large intertribal ties arose with the development of powerful, potentially militant and horse-mounted societies in the southern forest-steppe and steppe regions.

The presented models of the culture-historical development of human populations in Western Siberia and the hypothesized biological impacts that these influences have had on the inhabitants of the Barabinsk forest-steppe cannot conclusively resolve a discussion concerning the actual migration of human communities into this region. The assertion that populations displaying similar artifact assemblages and, by inference, similar levels of socioeconomic development are biologically related is unfounded. Likewise, the diffusion of material culture traits cannot be attributed directly to human migrations. However, radical changes in subsistence organization would appear to require extreme degrees of incentive, usually facilitated by changing environmental circumstances. The examination of subsistence organization alongside documented environmental changes provides insight into the ecological conditions and resultant choices available to populations before the occurrence of major economic transitional periods. This, in turn, provides greater insight into variables that may have stimulated population movements and the resultant spread of material culture throughout a region.

CHAPTER 2: THE SKELETAL SAMPLES

This chapter provides a detailed description of the sites, skeletal populations, skeletal sampling procedures and sex estimation analysis utilized in the study. A total of 308 Eneolithic, Krotovo Developed Bronze Age and Andronovo Developed Bronze Age skulls were examined. The great majority of the sample were excavated from Sopka-II (n=296). The small Andronovo sample from Sopka-II necessitated the addition of several crania from the Abramovo-IV (n=3), Preobrazhenka-III (n=8) and Vengerovo-I (n=1) burial sites. All of the sites are located along a 100 km stretch of the Om' river within Central Baraba (*cf.*, Figure 2.1). In addition, the temporal aspects of the burial populations at Sopka-II are examined and the resultant implications of chronological control on determinations of biological distance for prehistoric populations of the Baraba region are discussed.

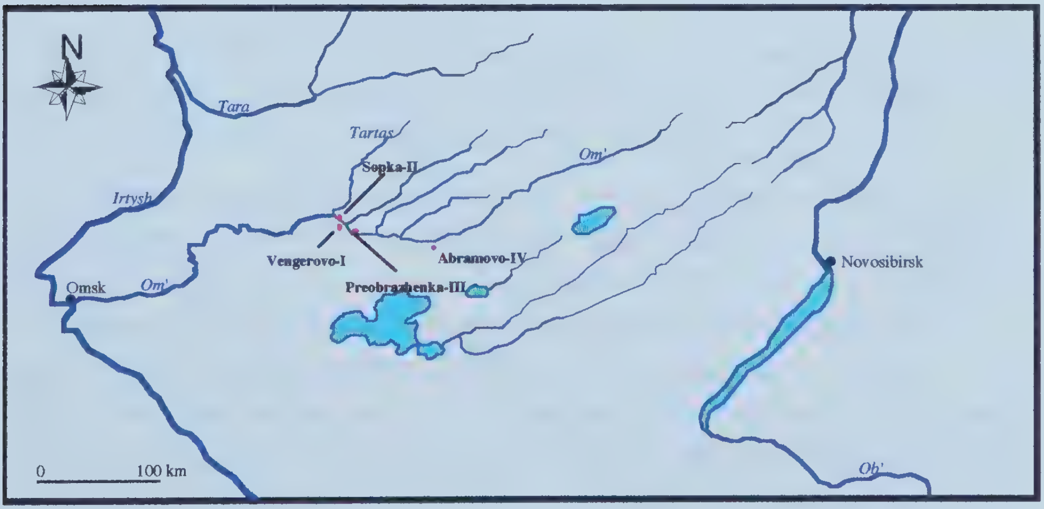


Figure 2.1 Map of the Barabinsk forest-steppe region and associated waterways (*cf.*, inset in Figure 1.2) displaying the Sopka-II, Vengerovo-I, Preobrazhenka-III and Abramovo-IV archaeological sites of the Central Baraba region.

1.0 THE ARCHAEOLOGICAL SITES AND SKELETAL POPULATIONS

1.1 Sopka-II

Sopka-II is located within the Vengerovo district of Central Baraba at the point of confluence of the Om' and Tartas rivers (*cf.*, Figure 2.1). In outward appearance, the site resembles a kurgan burial ground. However, excavation of the entire site area has revealed large Eneolithic and Developed Bronze Age cemeteries not associated with kurgans (Molodin 1995a). Molodin (1985, 1995a) has designated individual burials to discrete culture-historical periods on the basis of mortuary ritual and burial inventory. Further, he has identified spatially discrete burial areas which, in his opinion, represent distinct culture-historical groups. It is the present author's opinion that mortuary ritual is more conservative to change than material culture in prehistoric populations and would require a greater amount of incentive or external pressure to change. For this reason, mortuary ritual is given greater weight than material culture attributes in defining the skeletal samples utilized in the present study. Maps 1 and 2 display a simplified plan of the Sopka-II site which includes only those burials and kurgans directly attributed to the Eneolithic, Krotovo and Andronovo culture-historical periods.

A total of 69 crania comprise the Eneolithic sample in the present study. All were excavated from two discrete burial grounds located in the southern portion of Sopka-II near the Om' river (*cf.*, Maps 1 and 2). It is possible that this burial population is related to the nearby Sopka-III site which displays a cultural horizon containing typical Eneolithic 'pit-comb' pottery (Molodin 1994). The Eneolithic burial ritual is distinguished from the preceding Neolithic and later Krotovo burials by the small size of the burial ground, extended body placement in shallow burial pits, collective interment of adults of both sexes and infants, and the presence of typical Eneolithic pottery and grave goods (Molodin 1994). The easternmost cluster of Eneolithic burials is organized into well defined rows displaying similar grave orientations. This suggests that this group of burials was constructed over a relatively short and continuous period of time. The crania from both burial grounds were grouped together to form a single Eneolithic sample.

The Krotovo sample contains 220 crania excavated from 3 distinct burial grounds at the Sopka-II site. Several characteristics of mortuary ritual are commonly shared among

burials attributed to Krotovo times. These include interment in single burial pits, extended body position lying on the back, similar grave orientation from the northeast to the southwest, the presence of ochre, and rich burial inventories that vary according to sex, age and social rank (Molodin 1995a). Molodin (1995a), however, notes the existence of some mortuary variability. This variability is partly explained by the presence of Andronovo ceramic and bronze ornamental styles on many of the Krotovo burial items as well as the appearance of kurgan mortuary structures. The appearance of these cultural attributes and mortuary practices has led him to refer the entire Sopka-II assemblage to the second phase of the Krotovo culture (*i.e.*, late stages of the Samusko-Seyminskiy epoch) when contacts with populations representing the Andronovo cultural tradition are thought to have intensified.

Molodin (1995c) distinguishes three separate Krotovo burial grounds at Sopka-II on the basis of spatially discrete burial areas and subtle differences in mortuary ritual and burial inventory. For the purposes of this thesis, these burial grounds will be referred to as Developed Krotovo (Locality 1), Developed Krotovo (Locality 2) and Late Krotovo. These burial grounds may represent different chronological phases of interment at Sopka-II or could represent unidentified cultural processes (*i.e.*, differential access to burial grounds related to status or social differentiation) occurring during a continuous occupation of the site. Molodin (1995a:704-705) states that "... observations ... of the Sopka-2 burial rite and the occurrence of bronze weapons (several of which are typologically pronounced) ... have permitted to consider the collection as a culturally and chronologically single complex". In all probability, the cultural and spatial discreteness of the burial grounds at Sopka-II represent both cultural and chronological distinctions. However, Krotovo burial pits never disturb one another at the site suggesting that Sopka-II was utilized by Krotovo populations over a continuous and relatively short period of time (Molodin 1995a).

The Developed Krotovo (Locality 1) burial ground represents a circular cluster of Krotovo burial pits located along the western margin of the excavated area at Sopka-II (*cf.*, Maps 1 and 2). The cranial sample from Locality 1 includes 83 skulls. The contemporaneous nature of these graves is attested to by the clustered nature of the burial ground, their common orientation and the placement of burials in well-defined, linear rows. Molodin (1995c) suggests that this population is directly descended from

proceeding populations of the early phase of the Krotovo culture. As opposed to the remaining Krotovo burial grounds, Locality 1 lacks associated kurgan structures.

The Developed Krotovo (Locality 2) burial ground represents a cluster of pit and kurgan burials that extends in a linear fashion along the eastern embankment within the northern portion of Sopka-II (*cf.*, Maps 1 and 2). Locality 2 contains pit inhumations with similar characteristics of orientation, body placement and plan as observed in Locality 1, but with the addition of burials associated with kurgan mortuary structures. Many of the graves within Locality 2 are widely and unevenly spaced across this portion of the site and can occur some distance from the kurgan structures. Molodin (1995c) suggests that this population is also descended from the proceeding Early Krotovo culture with subtle typological differences from Locality 1 burials. Tentatively, Molodin suggests that the Locality 2 burial ground may be slightly younger than Locality 1. He also separates the burials of Locality 2 into those located under kurgans and those not associated with earth mounds but does not report further differences in mortuary ritual or grave goods between the two groups. The cranial nonmetric samples have likewise been grouped to reflect this distinction and are divided into separate Developed Krotovo (Locality 2) With Kurgan and Developed Krotovo (Locality 2) Without Kurgan components. A total of 58 crania were examined from Locality 2 burials not associated with earth mounds and 41 crania from the substratum of burials associated with kurgans.

The third burial ground of the Krotovo culture is located within the southern portion of the Sopka-II site and extends in a linear fashion along the eastern embankment (*cf.*, Maps 1 and 2). This burial ground is designated as Late Krotovo and contains simple pit inhumations as well as burials associated with kurgan structures. The pit inhumations of this cemetery are distinguished from Localities 1 and 2 by their consistent placement in close proximity to kurgans and their associated grave accompaniments. On the basis of increasing Andronovo cultural elements on the artifacts in these burials, Molodin (1995c) suggests that this is the most recent Krotovo burial ground represented at Sopka-II. These Late Krotovo populations are thought to have had direct and intensive contacts with populations of the Andronovo culture (Molodin 1995a). A total of 38 skulls were available for cranial nonmetric analysis from this series.

Few Andronovo graves have been discovered at the Sopka-II site (*cf.*, Maps 1 and 2) and it would be impossible to attribute these widely spaced graves as representative of a

homogeneous burial ground. Andronovo burials are readily distinguished from Krotovo graves by their distinct mortuary ritual (Molodin 1995b). The adult burials are usually interred under kurgans, although cremation is also common. The body is placed on either side in a flexed or semi-flexed position along with characteristic Andronovo ceramics (Molodin 1995b). On the contrary, sub-adult Andronovo individuals are typically interred in separate pit inhumation burial grounds as described below for Preobrazhenka-III. In contrast to Krotovo burials, Andronovo graves rarely contain weapons (Molodin 1995b). A total of 7 Andronovo crania were available for analysis from Sopka-II.

1.2 Abramovo-IV

The Abramovo-IV burial site is located in the Kubushevo district of Central Baraba on the southern bank of the Om' river (*cf.*, Figure 2.1). This site contains more than 100 kurgans belonging to different prehistoric periods (Molodin 1995b). Several of the excavated mounds contained Andronovo burials from which 3 crania proved suitable for analysis. The Andronovo burials from Abramovo-IV were identified on the same basic criteria as at Sopka-II and have been grouped with the small collection from the latter site.

1.3 Preobrazhenka-III

Preobrazhenka-III is a multi-component site containing burial grounds and settlement sites dating to various prehistoric periods. The site is located in the Chaniy district of Central Baraba on the northern bank of the Om' river (*cf.*, Figure 2.1). The Preobrazhenka-III site contains a large Krotovo settlement site, a large kurgan burial ground dating from the Andronovo epoch to later prehistoric times and a separate pre-adolescent cemetery belonging to the Andronovo culture (Molodin & Chikisheva 1988; Okladnikov & Molodin 1978). All adult burials of the Andronovo culture are situated under kurgans (Molodin 1995b). Eight adult crania from this burial ground were available for analysis. Since the Andronovo burials at Preobrazhenka-III are identified on the same basic criteria as at Sopka-II, the samples were combined.

1.4 Vengerovo-I

The Vengerovo-I burial site is located within the Vengerovo district of Central Baraba on the southern bank of the Om' river (*cf.*, Figure 2.1). The site represents a kurgan burial ground dating to the Andronovo, Early Iron and Middle Age periods (Molodin 1985:13). The Andronovo burial ritual at Vengerovo-I is extremely similar to those represented at Sopka-II. One adult skull was analyzed and added to the Andronovo cranial sample from Sopka-II.

2.0 THE SKELETAL SAMPLES

2.1 Sampling Procedures

The state of preservation of the skulls from Sopka-II was a major factor determining their inclusion in the nonmetric samples. Although loamy soil conditions in the Baraba region contribute to excellent skeletal preservation (Molodin 1995b), a significant proportion of skulls from the Sopka-II site were excluded from further analysis. Firstly, samples were excluded if advanced decomposition prevented the affirmation of post-adolescent age which was an initial sampling requirement. Post-adolescent age was determined by the observation of one of the following three criteria: spheno-occipital synchondrosis, eruption of the third permanent molar beyond the alveolar margin and/or moderate to advanced wear of the first or second adult molars (*cf.*, Buikstra & Ubelaker 1994). Further division of the adult skeletons into post-adolescent age groups was not performed since age-sensitive regions of the postcranial skeleton (*i.e.*, pubic symphysis, auricular surface and sternal rib ends) were not available for analysis and cranial-based age estimates such as cranial suture closure are prone to significant error (Masset 1989). In addition, age changes beyond maturity are not thought to greatly influence cranial nonmetric trait expression in humans (Hauser and De Stefano 1989:9). The Sopka-II cranial samples utilized in the present study represent the total number of available skulls of adult age that were scorable for at least one nonmetric trait.

2.2 Sex Estimation

The inability to determine sex with complete accuracy in human skeletons complicates sex variation tests. Ubelaker (1989:53-54) claims that correct estimation of sex nears 100% when using well-preserved pelvic bones and from 80 to 90% using cranial features. Sex estimation in the present study was based upon the qualitative assessment of sexually dimorphic features of the skull. A total of 18 features were examined for each skull (Buikstra and Ubelaker 1994:19-20; White 1991:16):

1. Glabella or nasal eminence
2. Slope of the forehead
3. Rugosity of temporal lines
4. Root of the zygomatic bone
5. Size of the mastoid process
6. External occipital protuberance
7. Shape of the chin
8. Shape of the ascending ramus
9. Gonial angle
10. Gonial eversion
11. Supraorbital ridge
12. Supraorbital margin or sill
13. Shape of the orbit
14. Shape of the foramen magnum
15. Shape of the palate
16. Rugosity of nuchal lines
17. Fronto-parietal bossing
18. Size of the occipital condyles

Each feature was attributed a score based upon the following 5 point scale: (1) 'male positive', (2) 'male probable', (3) 'indeterminate', (4) 'female probable', and (5) 'female positive'. A final sex assignment following the same 5 point scale was based upon the scores of all observable features. Table 2.1 presents the sex assessments for the six previously-defined cranial samples.

Culture	Male	Female	Indeterminate	Total
Eneolithic	48	20	1	69
Developed Krotovo (Locality 1)	51	28	4	83
Developed Krotovo (Locality 2) Without Kurgan	26	30	2	58
Developed Krotovo (Locality 2) With Kurgan	26	15	0	41
Late Krotovo	22	15	1	38
Andronovo	8	8	3	19
Total	**181**	**116**	**11**	**308**

Table 2.1 The results of sex designation analysis for the 6 cranial nonmetric samples.

A re-examination of 50 randomly chosen crania was performed to test for intraobserver scoring consistency in sex estimation. Sex estimates of 'male' (1 & 2),

'indeterminate' (3), and 'female' (3 & 4) were consistent between scoring trials in 92% of the cases (n=46). The 4 errors were never the result of 'male' versus 'female' misdesignations but rather to the attribution of 'indeterminate' sex in the corresponding scoring trial.

2.3 Chronological Considerations

A series of seven radiocarbon dates were obtained from human bone samples discovered in Neolithic, Eneolithic, Developed Krotovo and Late Krotovo burials at Sopka-II (*cf.*, Table 2.2). The radiocarbon date from the Neolithic burial lies beyond the

Lab Number	Sample Type	Sopka-II Burial	Archaeological Culture	Calculated ^{14}C Age (yrs B.P.)	Calibrated ^{14}C Age (yrs B.P.)*	Corrected ^{14}C Age (yrs BP)
BGS 1805	Human bone	68	Neolithic	7,170 +/- 100	7,940 +/- 100	8,005 +/- 100
BGS 1806	Human bone	655	Eneolithic	5,430 +/- 90	6,240 +/- 90	6,285 +/- 90
BGS 1807	Human bone	656	Eneolithic	5,660 +/- 90	6,420 +/- 90	6,470 +/- 90
BGS 1808	Human bone	491	Developed Krotovo (Locality 2) Without Kurgan	4,300 +/- 80	4,860 +/- 80	4,920 +/- 80
BGS 1809	Human bone	282	Developed Krotovo (Locality 1)	4,250 +/- 80	4, 830 +/- 80	4,895 +/- 80
BGS 1810	Human bone	325	Late Krotovo	3,825 +/- 80	4,180 +/- 80	4,280 +/- 80
BGS 1811	Human bone	335	Late Krotovo	4,100 +/- 90	4, 560 +/- 90	4,625 +/- 90

Table 2.2 Calculated, calibrated and isotopically corrected radiocarbon dates from Sopka-II (* - calibrated following the method of Stuiver and Pearson (1993)).

scope of this thesis but represents the oldest date obtained from the series. Corrected radiocarbon dates from two Eneolithic burials nearly bracket each other on their upper and lower limits of error and place this period of occupation within the 2nd half of the 5th millennium BC. A radiocarbon date obtained from human bone discovered in burial 282 suggests that the Developed Krotovo (Locality 1) burial ground was utilized at the onset of the 3rd millennium BC. A very similar date is obtained from burial 491 which belongs to the Developed Krotovo (Locality 2) Without Kurgan sample. The two dates obtained from Locality 1 and 2 suggest that these burial grounds may be contemporaneous, or at least that those Developed Krotovo burials not associated with kurgan structures date to

the first half of the 3rd millennium BC. No dates were obtained from burials associated with kurgans that belong to the Developed Krotovo (Locality 2) With Kurgan sample. An additional two radiocarbon dates were obtained from Late Krotovo burials. Although not internally uniform to a tight chronological period they are younger than the Eneolithic, Developed Krotovo (Locality 1) and Developed Krotovo (Locality 2) radiocarbon dates and are placed in the middle and latter half of the 3rd millennium BC. Although no radiocarbon dates were obtained from Andronovo burials at Sopka-II, Molodin (1995a) presents evidence from the Preobrazhenka-III site where Krotovo dwellings and burials were stratigraphically separated from overlying Andronovo cultural horizons. This evidence strongly supports the replacement of the Krotovo culture by the Andronovo cultural tradition in the Central Baraba region.

The small number of radiocarbon dates available for cranial samples from Sopka-II represent a major weakness of the present study. This series of dates, although supporting the relative chronological scheme presented by Molodin (1985, 1994, 1995a, 1995b), suggest a significantly earlier onset for the Eneolithic and Developed Bronze Age in the Baraba region. Figure 2.2 displays the seven radiocarbon dates alongside the generally accepted culture chronology for the region. If accepted, these radiocarbon dates would push back the onset of the Eneolithic and Developed Bronze Age over 1,000 years. McCormack and Baillie (1993) report that the corresponding calendrical band widths of calibrated radiocarbon dates from 5,300 to 4,000 BP are the least precise and accurate because this time represents the point of greatest rate of change of $\Delta^{14}C$ in the radiocarbon record. This problematic chronological interval brackets much of the prehistoric period of interest to the present study. Given the small number of radiocarbon dates available from Sopka-II, an explanation for the discrepancy between the relative culture-chronological and radiocarbon dating methods must await future investigation. The adherence of the dates to the relative chronological scheme is deemed as sufficient for testing biological differentiation between the diachronic skeletal samples from Sopka-II. In addition, the clustering of dates within the Eneolithic, Developed Krotovo and Late Krotovo samples suggest relative internal contemporaneity supporting the synchronic analysis of biological differentiation within the homogenous culture-historical groups.

Another important aspect concerning chronology is the duration of use of the burial grounds at Sopka-II. A major assumption behind the 'biological population' model is

that the skeletal samples represent a local interbreeding population. Cadien and coworkers (1974) criticize the use of prehistoric burial populations for testing biological distance and argue that skeletal samples are representative of human lineages and are not true interbreeding populations. In this sense, they define a lineage as a collection of temporally sequenced populations with genetic continuity. The small number of available radiocarbon dates from Sopka-II limit determinations, in absolute terms, of the duration of time represented by the separate burial grounds. The site plan of Sopka-II displays geographically distinct burial areas, internally homogenous burial groups, and linear burial arrangements that suggest continuous use of the burial site over short periods of time (*cf.*, Maps 1 and 2). However, it is probable that these periods of time lasted longer than one human generation and may have lasted several centuries. Thus, the cranial samples from Sopka-II are more likely representative of human lineages. While

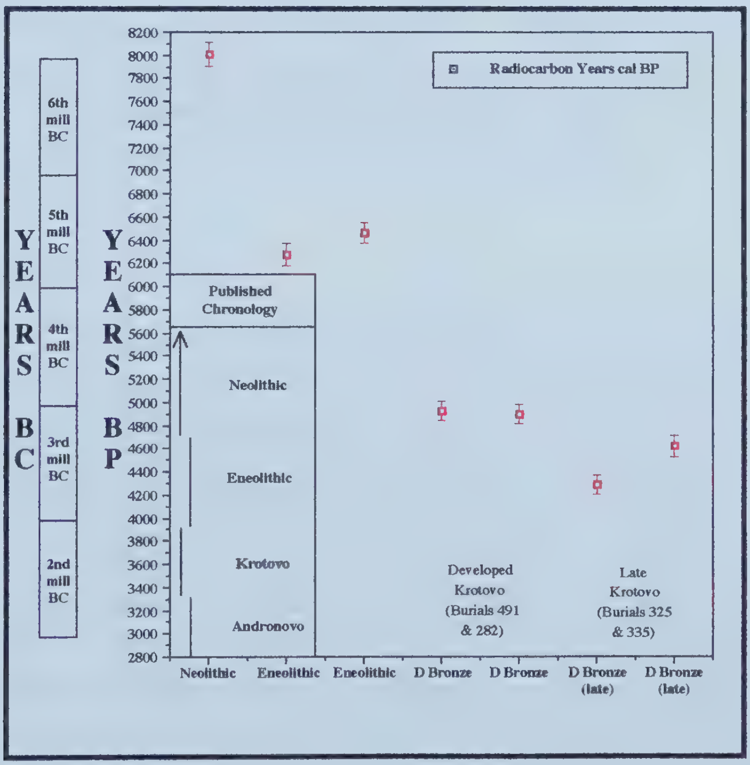


Figure 2.2 The calibrated radiocarbon dates obtained from Sopka-II in comparison with the generally accepted culture chronology for the Baraba region.

recognizing the theoretical limitation of the cranial samples from the Sopka-II site, it is rare to encounter a burial ground with superior chronological, spatial and culture-historical controls for delineating prehistoric burial groups. Thus, this study will assume that directional micro-evolutionary change resulting from the processes of mutation and natural selection would not have greatly affected the genetic constitution and resultant phenotypes of these populations over the span of a few generations. In this sense, the individual cranial samples can be regarded as genetically homogeneous. However, these microevolutionary forces may have affected the gene pool of local populations over the several millennia represented by the temporally separated cranial samples. Cadien *et al.* (1974) point out that stochastic microevolutionary events, such as population migrations (*i.e.*, gene flow) or restrictions of the local gene pool through isolation or status differentiation (*i.e.*, genetic drift), could have significantly affected the genetic constitution of small populations over the period of only several generations. The microevolutionary processes of gene flow and genetic drift have the potential for producing significant biological differentiation within the periods of time represented by the synchronic population samples examined in the present study.

3.0 SUMMARY

The cranial nonmetric samples examined in this thesis are representative of burial populations distinguished on the basis of cultural uniformity in mortuary ritual and grave goods and/or spatial discreteness of the burial areas at Sopka-II. Green and Suchey (1976) point out that population samples of 30 or more individuals are necessary in order to stabilize the variance associated with transforming cranial nonmetric frequencies for the purpose of constructing biological distance coefficients (*cf.*, Chapter 4). All of the Siberian cranial samples except the Andronovo subset (n=19) conform to this recommendation. The Andronovo sample, however, represents the maximum number of crania that were available for analysis from the Central Baraba region. In addition, the relative chronological placement of the cranial samples has been tentatively established through consideration of relative dating methods and the few radiocarbon dates that were obtained. The culture-historical processes represented by the observed typological shifts at Sopka-II have been shown in the previous chapter to be associated with unique

historical processes, environmental changes, shifting subsistence strategies and hypothesized population migrations across the entire region of Western Siberia. Thus, the present cranial nonmetric samples can be used to test the biological effects of these processes within and between human populations representing the Eneolithic, Krotovo and Andronovo Developed Bronze culture-historical periods in the Baraba region.

CHAPTER 3: METHODS OF CRANIAL NONMETRIC ANALYSIS

The following chapter presents the analytical methodology employed in this study. Nonmetric biological distance studies demand the employment of rigorous methodological constraints to ensure standardized presentation and consistent scoring of the morphological features and to limit the effects of non-genetic factors in the results. Contemporary research tends to follow a 'reductionist' model advocating the analysis of distributional characteristics in nonmetric data and supporting the elimination of traits that are correlated with one another, are influenced by differences in side, age or sex, are inconsistently scored, or that display significant non-genetic factors in their expression. In practice, however, most research designs represent a compromise between the above considerations and an attempt to include as many skeletal variants as possible in order to maximize the amount of 'morphogenetic' information represented by biological distance coefficients (Molto 1983:132). This chapter first considers the detailed criteria employed during the trait selection process. This is followed by a trait by trait description of the nonmetric variants that define the selected scoring procedures. A test of intraobserver scoring consistency is intended to test the effectiveness of the implemented scoring methods. In addition, the results of statistical tests on distributional aspects of the nonmetric data concerning the effects of sex and side on nonmetric trait expression are also presented. A similar analysis for age differences was not conducted since only adult crania were examined and the effects of adult age on nonmetric trait expression are negligible (Hauser and De Stefano 1989:9). An examination of intertrait correlation was also excluded due to the small sample sizes in which case the intercorrelation of traits is thought not to affect biological distance coefficients to a greater extent than would the random fluctuation of independent variants (Sjøvold 1977b). Lastly, since all nonmetric data were collected by the author, a statistical test for interobserver scoring error was not required.

1.0 TRAIT SELECTION

The purpose of the trait selection process is to select the maximum number of independently expressed, genetically determined and consistently scorable cranial and mandibular nonmetric variants. Nonmetric traits of the infracranial skeleton were not considered due to logistical problems of matching the Siberian skulls with their associated postcranial skeletons. Trait selection was based upon previously published

descriptions of nonmetric variants presented by Berry and Berry (1967), Buikstra and Ubelaker (1994), Hauser and De Stefano (1989), Lovell (1994), Molto (1983), Ossenberg (1969), and Rose *et al.* (1991). A total of 52 cranial nonmetric variants were initially selected for consideration in this study. This number represents just over one quarter of the more than 200 nonmetric traits previously described for the skull (Ossenberg 1976).

The reduction in the number of traits considered in this study reflects the employment of several selective criteria in the initial trait selection process. An initial concern was the selection of skeletal variants that score independent aspects of cranial nonmetric variation, especially since a test for trait interdependence was not conducted. Thus, for potentially conflicting traits such as *apical bone present* and *sagittal suture ossicle* that would otherwise score identical manifestations of the skeleton as 'present', only one or the other was included within the trait list.

A second concern was the elimination of those variants whose development are known to be significantly determined by nongenetic factors such as dietary, pathogenic, functional or mechanical influences. As a result, the initial trait list did not include variants such as the *highest nuchal line* (Corruccini 1974), *mandibular, maxillary and palatine tori* (Halfmann, *et al.* 1992; Larnach 1974; Mayhall 1970), and *marginal, malar and zygomaxillary tubercles* (Melbye 1969) since the expression of these traits is thought to be influenced as much by mechanical factors as by genes (Molto 1979). It should be noted that the etiologic basis underlying the expression of the majority of nonmetric variants is still poorly known and, perhaps, would have resulted in further trait exclusions.

A third consideration was the elimination of nonmetric traits that are difficult to score consistently when using a dichotomous scoring standard. Several authors have noted difficulties in scoring traits that involve the identification of foraminal location in relation to sutures (De Stefano *et al.* 1984; Larnach 1974; Rösing 1984) and the presence of supernumerary bones in cases of advanced sutural synostosis (Larnach 1974). As a result of these reports, and in accordance with the author's own observations in the laboratory, the *anterior ethmoid foramen exsutural*, *posterior ethmoid foramen present* and *mastoid foramen exsutural* were eliminated because of difficulties associated with scoring these portions of the medial orbital and occipitomastoid regions of the skull.

A list of the 52 selected traits, including their abbreviated forms, is presented in Table 3.1. For comparative purposes, the trait nomenclatures of both Cesnys and Pavilonis (1982) and Movsesyan *et al.* (1975) also are presented; the former because of its widespread usage in Europe, and the latter because of its common use in regions of the former Soviet Union[1].

The nonmetric variants in Table 3.1 are further categorized in accordance with a modified version of the general classification scheme presented by Ossenberg (1969). This classification scheme includes five separate trait categories which in order of appearance in Table 3.1 are:

1. Hyperostotic traits: This category denotes traits that display an excess of ossification in comparison to the normal or non-pathogenic state. This is generally manifest in the ossification of structures normally composed of cartilage, ligaments or other soft tissues;

2. Hypostotic traits: These traits are characterized either by the retarded ossification of normally osseous structures or arrested development representing the retention of an immature or embryonic stage of development in the adult skeleton;

3. Foramina, canals and grooves: This trait category reflects osseous structures that are the direct result of the presence, absence or variable course of blood vessels and nerves;

4. Accessory bones of the cranial vault and sutural variations: This category reflects extra or supernumerary bones situated along various sutures and at several ectocranial points of the cranial vault. Also included in this category are traits scoring deviant sutural configurations or patterns; and,

5. Unclassified traits: These traits are difficult to classify in the previously noted categories and thus are given a separate grouping.

Despite the fact that some traits do not fit neatly into one or another category, the system provides a useful set of classifications against which directional biases inherent in distributional aspects of the cranial nonmetric data can be contrasted and compared.

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[1] For those variants not included within the above studies, the Latin trait nomenclatures of Hauser and De Stefano (1989) have been substituted wherever possible.

Table 3.1 - The Nonmetric Trait List, Abbreviations and Standardized Nomenclatures

		Standardized Nomenclatures		
Traits by Type	**Abbreviations**	**Cesnys & Pavilonis (1982)**	**Movsesyan *et al.* (1975)**	**Hauser and De Stefano (1989)**
Hyperostotic traits:				
1 Auditory torus √	AudTorus	Torus acusticus	Torus tympanicus	-
2 Marginal foramen √	MargFor	-	-	Foramen marginale
3 Precondylar tubercle √	PrecondTub	Tuberculum precondylare	Condylus tertius	-
4 Ossified apical ligament	OsApiLig	-	-	-
5 Clino-clinoid bridge √	ClinoCBri	-	-	Ponticuli sellae
6 Carotico-clinoid bridge √	CarotCBri	-	-	Ponticuli sellae
7 Paracondylar process √	PCondPro	-	-	Processus paracondylaris
8 Intermediate condylar canal √	IntCondCan	-	-	Canalis condylaris intermedius
9 Anterior condylar canal double √	AntCondCan	Canalis hypoglossalis septus	-	-
10 Pterygo-alar bridge (partial) √	PterABr	-	-	Ponticulus pterygo-alaris
11 Pterygo-spinous bridge (partial) √	PterSBr	Arcus pterygospinosus	Foramen pterygospinosum	-
12 Trochlear spur √	TrochSpur	-	-	Spina trochlearis
13 Mylohyoid arch √	MylohA	Arcus mylohyoideus	Arcus mylohyoideus	-
14 Lingula bridge √	LingBri	-	-	-
15 Genial tubercles	GenTub	-	-	Tubercula genialia
16 Median mental spine	MMentSp	-	-	Spina mentalis
Hypostotic traits:				
17 Biasterionic suture √ *	BiAstSut	-	-	Sutura mendosa
18 Tympanic dehiscence √	TympDeh	Foramen tympanicum	Foramina tympanica	-
19 Foramen ovale incomplete √	ForOvInc	Foramen ovale incompletum	-	-
20 Foramen spinosum open √	ForSpinOp	Foramen spinosum incompletum	Foramen spinosum (absent)	-
21 Os japonicum (trace) √	OsJap	Sutura zygomatica	Os zygomaticum bipartitum	-
22 Metopism	Metop	Sutura frontalis (metopica)	Sutura frontalis	-
23 Infraorbital suture (trace) √	InfOSut	-	-	Sutura infraorbitalis
24 Genial pits	GenPit	-	-	Foveola mentalis

Legend: √ - bilateral nonmetric variant; * - this trait could also be classified in the suture/ossicle category

Table 3.1 - Continued

		Standardized Nomenclatures		
Traits by Type	**Abbreviations**	**Cesnys & Pavilonis (1982)**	**Movsesyan *et al.* (1975)**	**Hauser and De Stefano (1989)**
Foramina, canals and grooves				
25 Parietal foramina √	ParFor	Foramen parietale	Foramina parietalia	-
26 Obelionic foramen	ObelFor	-	-	-
27 Superior sagittal sulcus turns right	SSSTR	-	-	-
28 Parietal process of temporal √	ParProcT	-	-	Processus parietalis squamae temporalis
29 Posterior condylar canal patent √ **	PCondCan	Canalis condylaris	Canalis condyloideus	-
30 Accessory lesser palatine foramen √	AccLPalFo	Foramen palatinum accessorium	-	-
31 Zygomaticofacial foramen double √	ZygFacFor	Foramen zygomaticofaciale	Foramina zygomaticofacialia	-
32 Supraorbital foramen (complete) √	SupOrbFor	Foramen supraorbitale	Foramina supraorbitalia	-
33 Frontal foramen or notch √	FroFor	Foramen frontale	Foramina frontalia	-
34 Accessory supraorbital foramina √	AccSupOFor	-	-	-
35 Frontal grooves √	FroGroove	-	-	Sulci frontales
36 Supratrochlear notch or canal √	SupTNot	-	-	Incisura supratrochlearis
37 Accessory infraorbital foramen √	AccInfOFor	Foramen infraorbitale accessorium	Foramina infraorbitalia	-
38 Accessory mental foramen √	AccMentFor	Foramen mentale accessorium	Foramina mentalia	-
Accessory bones of the cranial vault and sutural variations:				
39 Ossicle at lambda	OsLam	Os lambdae	Os apicis lambdae	-
40 Inca bone	IncaB	Os interparietale	Os Incae	-
41 Lambdoidal suture ossicle √	LambSutOs	Ossa suturae lambdoideae	Os Wormii suturae lambdoideae	-
42 Ossicle at Asterion √	OsAst	Os asterii	Os asterion	-
43 Bregmatic bone	BregBone	Os bregmae	Os Bregmaticum	-
44 Coronal suture ossicle √	CorSutOs	Ossa suturae coronalis	Os Wormii suturae coronalis	-
45 Sagittal suture ossicle	SagSutOs	Ossa suturae sagittalis	Os Wormii suturae sagittalis	-
46 Epipteric bone √	EpiBone	Os pterii	Os epiptericum	-
47 Parietal notch bone √	ParNotBone	Os incisurae parietalis	Os postsquamosum	-
48 Occipitomastoid suture ossicle √	OcMastSutOs	-	-	Ossicula suturae occipitomastoideae
49 Nasal bone variation	NasBone	-	-	-
50 Frontotemporal articulation √	FroTempArt	Sutura frontotemporalis	Stenokrotaphia	-
Unclassified traits:				
51 Condylar facet double (partial) √	CondFacDo	Facies articularis condylaris bipartita	Condylus occipitalis bipartitus	-
52 Rocker jaw	RockJaw	-	-	-

<u>Legend:</u> √ - bilateral nonmetric variant; ** - this trait could also be classified in the hypostotic category

2.0 TRAIT SCORING

The standardization of nonmetric trait scoring procedures is necessary in order to maximize intraobserver scoring consistency and to increase the comparability of biological distance data with present and future studies. Data collection in this study was guided by precise definitions of trait thresholds and scoring procedures. The trait descriptions are presented in Appendix A and include information concerning the original sources of the scoring methods and references to illustrations and photographs existing in the literature. For those traits displaying more or less continuous variation, the numerous trait thresholds that are observed and the method of dichotomizing these data for the compilation of trait frequencies is also presented. The data are organized according to the same modified version of Ossenberg's (1969) classification scheme as in Table 3.1 and include the chosen abbreviated forms and the results of a test for intraobserver error. A general discussion concerning the employed scoring methods is presented below.

Following the recommendations of Buikstra and Ubelaker (1994), several guidelines for the scoring of nonmetric traits have been applied. Firstly, it is necessary to record positive occurrences, absences and instances when observation of the variants are not possible. Secondly, bilateral traits must be scored separately by side in order to allow for the analysis of side differences (*i.e.*, laterality) and symmetry as well as to facilitate the examination of biological distance coefficients using a variety of known scoring methods (*i.e.*, 'side' vs. 'individual' trait frequencies).

The scoring of accessory ossicles of the cranial vault require the application of stringent scoring guidelines because of difficulties encountered when the cranial sutures are fragmented or fused over part or all of their length. If less that two thirds of the suture is fused or not available for observation then it is scored as 'unobservable' when no sutural ossicles are present. No size limitation was imposed as long as the sutural bone was clearly defined. Small ossicles resulting from the interdigitation of complex sutural patterns were scored as 'absent'.

The nonmetric trait data were compiled for the six Siberian skeletal samples and are presented in Appendix B. The number of 'positive' scores (n), the total number of observations (N), the incidence of the trait in each sample, and the number of

unobservable observations are included for both the 'individual' and 'side' scoring methods. In the absence of both sides for analysis when recording 'individual' observations, unilateral occurrences of bilateral trait expressions were considered as representative of the individual and used to score 'present' or 'absent' manifestations.

2.1 Intraobserver Scoring Consistency

The majority of skeletal nonmetric studies have assumed that the effects of observer error are minimized when data are collected by a single individual. Despite this common assumption, the few studies that have formally investigated this problem have revealed the production of significant errors between subsequent scoring trials of nonmetric variants by the same researcher (Finnegan 1978; Molto 1979). In fact, Molto (1979) observes that problematic traits can contribute a greater than expected amount to biological distant coefficients which could lead to the complete reversal of results between selected and composite traits lists (*i.e.,* the production of Type 1 statistical errors). For this reason, a random subset of 50 Siberian crania were rescored for all 52 cranial nonmetric traits and the effects of intraobserver scoring consistency were examined.

The conventional method of examining intraobserver error is to determine the number of recording errors and divide this value by the total number of observations, eliminating those traits that are subject to greater than 5% error (Korey 1970; Molto 1983; Sofaer *et al.* 1986). The phi coefficient is a more powerful statistic for testing intraobserver scoring precision since it measures both the strength of the correlation between scoring trials and also the agreement between the two analyses for classifying each variant the same (Molto 1983:106). The phi coefficient is calculated as follows:

$$\phi = \frac{P_{11}P_{22} - P_{12}P_{21}}{\sqrt{(P_1\bullet)(P\bullet_1)(P_2\bullet)(P\bullet_2)}}$$

where P_{11} = common absence recorded in both analyses
P_{22} = common presence recorded in both analyses
P_{12} = scored present in first analysis and absent in second analysis
P_{21} = scored absent in first analysis and present in second analysis
$P_1\bullet$ = sum of $P_{11} + P_{12}$
$P\bullet_1$ = sum of $P_{11} + P_{21}$
$P_2\bullet$ = sum of $P_{21} + P_{22}$
$P\bullet_2$ = sum of $P_{12} + P_{22}$

Since a phi value represents a correlation coefficient, it displays a theoretical range between -1 and +1. Thus, a phi coefficient of +1 will result from perfect agreement between the two analyses (*i.e.*, if $P_{12} = P_{21} = 0$), a coefficient of 0 represents the absence of association between the two analyses (*i.e.*, if $P_{11}P_{22} = P_{12}P_{21}$), and a value of -1 will result from perfect disagreement between the two analyses (i.e., if $P_{11} = P_{22} = 0$). It is difficult to conceptualize the degree of association represented by correlation coefficients since the statistic represents a ratio between the results of separate scoring trials that tells little of the shared variance. In interpreting the significance of a phi statistic, it is more useful to look at the square of the phi value, the coefficient of determination (r^2), which expresses the proportion of the total variability among the scores of one analysis that can be explained by the observed variance in the scores of a second scoring trial (Spence *et al.* 1983:96-97). For example, given phi = ± 0.80 then $r^2 = 0.64$ and 64 percent of the variability in the first analysis can be accounted for by variations observed in the second analysis.

The results of intraobserver scoring consistency for the chosen trait list are presented in Table 3.2. The phi coefficient, the coefficient of determination and the incidence of recording errors (*i.e.*, total number of errors / total number of observations) are listed for each nonmetric trait and sorted in descending order by the phi-squared values. A variable degree of scoring consistency is observed across the trait list. The incidence of scoring error ranges from between 0% and 22.9%, with 32 traits (62%) falling within 5% confidence limits and 47 traits (90%) falling within 10% confidence limits. As expected, the majority of the traits display high correlation between the scores of the first and second trials with only 7 traits dropping below a 0.7 phi coefficient value. However, at this value, only 50% of the variability in the first set of scores would predict similar variability in the second trial which would appear unacceptable when employing a dichotomous scoring standard.

A problem in the assessment of intraobserver scoring consistency is the lack of standardized and objective methods for determining acceptable levels of error for individual traits. The traditional method of accepting only those traits that fall within the 5% level of error is not desirable since this error value may not represent a high correlation between separate scoring trials. An example from the Siberian data is *carotico-clinoid bridge (Trait 6)* which, while displaying a 4.8% level of error, was

Table 3.2: Test of Intraobserver Scoring Precision of Nonmetric Variants (n=52) Sorted in Decreasing Order by the Phi(ø)-Squared Coefficient

Trait	P11	P22	P12	P21	P1•	P2•	P•1	P•2	Ø	r2	% error
9 AntCondCan	81	12	0	0	81	12	81	12	1.000	1.000	0.000
12 TrochSpur	93	6	0	0	93	6	93	6	1.000	1.000	0.000
22 Metop	50	1	0	0	50	1	50	1	1.000	1.000	0.000
24 GenPit	0	46	0	0	0	46	0	46	1.000	1.000	0.000
28 ParProcT	98	2	0	0	98	2	98	2	1.000	1.000	0.000
34 AccSupOFor	97	3	0	0	97	3	97	3	1.000	1.000	0.000
39 OsLam	44	3	0	0	44	3	44	3	1.000	1.000	0.000
40 IncaB	49	0	0	0	49	0	49	0	1.000	1.000	0.000
43 BregBone	47	0	0	0	47	0	47	0	1.000	1.000	0.000
45 SagSutOs	80	2	0	0	80	2	80	2	1.000	1.000	0.000
50 FroTempArt	84	0	0	0	84	0	84	0	1.000	1.000	0.000
52 RockJaw	87	9	0	0	87	9	87	9	1.000	1.000	0.000
46 EpiBone	70	9	1	0	71	9	70	10	0.942	0.887	0.013
41 LambSutOs	71	20	1	1	72	21	72	21	0.938	0.881	0.022
25 ParFor	17	79	0	2	17	81	19	79	0.934	0.873	0.020
18 TympDeh	75	18	0	3	75	21	78	18	0.908	0.824	0.031
20 ForSpinOp	55	37	2	3	57	40	58	39	0.893	0.798	0.052
19 ForOvInc	91	4	1	0	92	4	91	5	0.890	0.791	0.010
13 MylohA	87	4	1	0	88	4	87	5	0.889	0.791	0.011
8 IntCondCan	51	31	1	4	52	35	55	32	0.881	0.776	0.057
32 SupOrbFor	85	12	0	3	85	15	88	12	0.879	0.773	0.030
27 SSSTR	9	38	1	1	10	39	10	39	0.874	0.765	0.041
31 ZygFacFor	72	17	1	3	73	20	75	18	0.870	0.756	0.043
21 OsJap	70	7	0	2	70	9	72	7	0.870	0.756	0.025
5 ClinoCBri	83	3	0	1	83	4	84	3	0.861	0.741	0.011
10 PterABr	72	21	0	6	72	27	78	21	0.847	0.718	0.061
51 CondFacDo	61	22	0	6	61	28	67	22	0.846	0.715	0.067
42 OsAst	79	6	1	1	80	7	80	7	0.845	0.713	0.023
14 LingBri	26	61	6	1	32	62	27	67	0.834	0.696	0.074
2 MargFor	73	11	0	4	73	15	77	11	0.834	0.695	0.045
4 OsApiLig	20	6	0	2	20	8	22	6	0.826	0.682	0.071
37 AccInfOFor	60	22	0	7	60	29	67	22	0.824	0.679	0.079
3 PrecondTub	68	18	4	2	72	20	70	22	0.817	0.667	0.065
44 CorSutOs	79	2	0	1	79	3	80	2	0.811	0.658	0.012
48 OcMastSutOs	72	2	0	1	72	3	73	2	0.811	0.658	0.013
11 PterSBr	91	4	2	0	93	4	91	6	0.808	0.652	0.021
49 NasBone	22	15	2	2	24	17	24	17	0.799	0.638	0.098
36 SupTNot	86	11	4	1	90	12	87	15	0.793	0.630	0.049
26 ObelFor	28	17	3	2	31	19	30	20	0.791	0.625	0.100
35 FroGroove	68	20	3	5	71	25	73	23	0.779	0.607*	0.083
29 PCondCan	16	52	1	6	17	58	22	53	0.770	0.593	0.093
47 ParNotBone	81	7	1	3	82	10	84	8	0.760	0.577	0.043
16 MMentSp	29	12	2	3	31	15	32	14	0.749	0.561	0.109
30 AccLPalFo	22	64	10	1	32	65	23	74	0.743	0.552	0.113
33 FroFor	86	8	5	1	91	9	87	13	0.710	0.504	0.060
6 CarotCBri	74	5	3	1	77	6	75	8	0.697	0.486	0.048
15 GenTub	2	42	0	2	2	44	4	42	0.691	0.477	0.043
38 AccMentFor	56	25	2	14	58	39	70	27	0.664	0.440	0.165
7 PCondPro	26	29	2	12	28	41	38	31	0.628	0.394	0.203
17 BiAstSut	78	8	2	7	80	15	85	10	0.604	0.365	0.095
23 InfOSut	3	61	1	6	4	67	9	62	0.458	0.209	0.099
1 AudTorus	72	2	1	21	73	23	93	3	0.180	0.032	0.229

Legend: * - cut-off trait at 0.65 phi-squared value

incorrectly scored as 'absent' in 4 out of 9 cases in which a 'present' score was observed in the corresponding analysis. Molto (1979) follows a phi-squared threshold of 0.7 for assessing scoring repeatability but admits that this value is somewhat high and "... that the cranial sample for determining scoring precision was "ideal" in that the crania were reasonably complete and well preserved" (Molto 1979:342). Given the variable, and often poor state of preservation represented by the random sample of crania selected for the assessment of intraobserver error in the present study, it would seem reasonable to reduce this threshold of tolerance. In fact, the acceptable scoring threshold followed in the current study was dropped to a phi-squared value of 0.65. The incidence of scoring errors within this subset of traits (n=36) ranges from between 0% and 7.9% with only 8 of the 36 nonmetric variants exceeding the 5% level of error. The acceptance of this level of scoring error is not unprecedented since Nichol and Turner (1986) have accepted up to 10% error levels for dental variants displaying two or more degrees of expression. If the scoring threshold would have been maintained at the recommended 0.70 phi-squared value or dropped to a phi-squared value of 0.60, the upper range of error would have been 6.7% and 10.0%, respectively.

A total of 16 nonmetric traits display unacceptable levels of intraobserver scoring consistency as presently defined and will be excluded from further consideration in this analysis. These are:

1. Auditory torus
6. Carotico-clinoid bridge
7. Paracondylar process
15. Genial tubercles
16. Median mental spine
17. Biasterionic suture
23. Infraorbital suture (trace)
26. Obelionic foramen
29. Posterior condylar canal patent
30. Accessory lesser palatine foramen
33. Frontal foramen or notch
35. Frontal grooves
36. Suptratrochlear notch or canal
38. Accessory mental foramen
47. Parietal notch bone
49. Nasal bone variation

From this point forward, only the remaining consistently scored traits (n=36) will be considered.

A closer examination of the intraobserver scoring error data reveals several inconsistencies of the employed scoring methods. The distribution of error for the *auditory torus (trait 1)* and *paracondylar process (trait 7)* reveal a tendency for heightened detection during the second scoring trial. The errors produced for the remaining hyperostotic traits, *carotico-clinoid bridge (trait 6)*, *genial tubercles (trait 15)*

and *median mental spine (trait 16)*, do not allow interpretations of similar directional scoring biases. It should be mentioned, however, that particular difficulty was noted in observing the 'presence' or 'absence' of contact spurs in the carotico-clinoid bridge. It is likely that this resulted in the traits reduced scoring consistency. Only two hypostotic variants display poor scoring consistency, *biasterionic suture (trait 17)* and *infraorbital suture (trait 23)*, and the distribution of error for both of these traits reflects a systematic bias towards heightened detection during the second scoring trial. A number of foraminal traits (n=7) were inconsistently scored. The scoring errors for *posterior condylar canal patent (trait 29)* and *accessory mental foramen (trait 38)* display a distinct bias towards detection in the second scoring trial while *accessory lesser palatine foramen (trait 30)*, *frontal foramen or notch (trait 33)* and *supratrochlear notch or canal (trait 36)* display a tendency for being observed as 'present' during the first scoring trial and 'absent' during the second analysis. The remaining poorly scored foraminal traits, *obelionic foramen (trait 26)* and *frontal groove (trait 35)*, do not allow interpretations of similar directional scoring biases. A potential explanation for the poor consistency in scoring the presence of *frontal foramen or notch (trait 33)* is the confusion presented by numerous crania in discerning between manifestations of this trait and *accessory supraorbital foramina (trait 34; cf.* Appendix A). One trait scored poorly in the sutural ossicle and variation category, *parietal notch bone (trait 47)* as well as an additional trait from the unclassified trait category, *nasal bone variation (trait 49)*. However, the distribution of scoring errors for these variants do not permit the interpretation of systematic recording biases.

Several general results can be forwarded from the above observations. Firstly, foraminal variants are the most problematic traits in the present study representing nearly 40% of the poorly scored variants (n = 16). This supports Ossenberg's (1974) claim that the expression of foraminal traits is often too ambiguous to be meaningfully classified using a dichotomous scoring standard. In addition, the distribution of scoring errors across all trait categories reveal a general tendency for traits to be more commonly scored as 'present' during the second scoring trial which was conducted after the full range of nonmetric variation represented in the Siberian cranial samples had been observed. This could represent either a learning curve in the ability to detect the presence of certain nonmetric variants or the inadvertent modification of the scoring criteria during the course of data collection. Concerning the latter possibility, Sofaer and coworkers (1986) report a tendency of changing the weight of scores for traits that are especially rare or

common. Regardless of the underlying cause, the results of this test underline the need for continued diligence in examining intraobserver scoring consistency in skeletal nonmetric studies. In addition, it is suggested that conducting a preliminary examination of the full range of nonmetric variation represented in cranial samples before proceeding with data collection would significantly enhance scoring consistency.

3.0 DISTRIBUTIONAL PROPERTIES OF NONMETRIC VARIATION

An examination of the distributional aspects of skeletal nonmetric variation in the Siberian cranial samples was performed in order to identify those traits displaying significant differences in trait incidence by sex and by side. The goal was to identify directionality in trait distributions across the separate samples that show tendencies for expression in one or the other sexes or sides and the subsequent elimination of these variants from the trait list. The rationale behind this process of elimination is that directional differences in trait incidence reflect the influence of non-genetic factors (*i.e.*, environmental, developmental or physiological influences) in the expression of nonmetric variants that would dilute the relevancy of population comparisons for measuring genetic relationships between past human groups. Furthermore, the recognition and rejection of these traits allows the pooling of crania by sex and by side, effectively increasing sample sizes and allowing fragmentary, unsexable skeletons to be included within population comparisons. The results of the sex and side analysis for each skeletal sample are presented below and are compared to baseline results derived from a pooled sample of all crania examined in this study.

3.1 Sex Differences

The examination of sexual dimorphism was facilitated by arranging the data for the 36 consistently scored nonmetric variants into a two-by-two contingency table and using the chi-squared statistic to measure the significance of frequency differences between the male and female samples. It is assumed that sexually dimorphic variation in the human cranium is expressed along a bimodal distribution, with the majority of skulls displaying manifestations that comfortably fit it into one or the other sex designations but with a few crania from both sexes occupying the intermediate position. Skulls assigned an ‘indeterminate’ sex designation are thought to occupy the intermediate position in the

bimodal distribution of sexual dimorphic expression. Thus, only those crania attributed 'male positive', 'male probable', 'female positive' and 'female probable' sex designations are included in the following analysis. The data are arranged as follows:

	Sex	
	Female	Male
Trait Present	a	b
Trait Absent	c	d

The chi-squared test statistic is

$$X^2 = \frac{n(ad-bc)^2}{(a+b)(a+c)(b+d)(c+d)}$$

where n = a + b + c + d, the number of crania for which the trait can be scored in the male or female samples, as defined above. Following Thomas' (1976:298) guidelines, the standard Pearson's chi-squared test is applied in every case when n is greater than 40 and the smallest expected cell frequency (E_i) is greater than 10 or when n is between 20 and 40 and the smallest expected cell frequency (E_i) is greater than 10. The Yate's Correction for Continuity is applied to the above chi-squared test when n is greater than 40 and the smallest E_i drops anywhere below 10 or when n is between 20 and 40 and the smallest E_i falls between 5 and 10. The Fisher's Exact Test is applied when n is less than 20 or when n is between 20 and 40 and the smallest E_i falls below 5.

The sex data and the results of the chi-squared test for sex differences in trait incidence are presented in Appendix C beginning with a pooled sample of the Siberian crania and followed by the six separate population samples. In the pooled sample, 4 out of 35 (11.43%) observable traits display significant differences in trait incidence between the sexes. This percentage exceeds the number of traits that would be expected to significantly differ by chance alone. The commonly reported association between hyperostotic traits and higher male incidence and hypostotic traits and higher female incidence (Molto 1983; Ossenberg 1969; Saunders 1978) is observed in the pooled sample of Siberian crania. The one hyperostotic trait, *pterygo-spinous bridge (trait 11)* , displays a higher incidence in the pooled male sample and the hypostotic trait, *foramen spinosum open (trait 20)*, displays higher incidence in the pooled female sample. In addition, one sutural variant, *sagittal sutural ossicle (trait 45)*, displays higher prevalence

among the pooled male sample and an unclassified trait, *rocker jaw (trait 52)*, reveals higher female incidence.

In determining the significance of the sex differences represented in the pooled sample of Siberian crania it is useful to compare these results with those obtained for the individual samples. Corruccini (1974) stresses the importance of this procedure since significant sex differences among separate sample populations could be canceled out in the process of summing trait frequencies. A comparison of the number of traits that display significant sex differences in the pooled and individual cranial samples is presented in Table 3.3. In contrast to Corruccini's (1974) assertion, the results for the Siberian crania reveal that a greater number of sex differences are produced as a result of pooling the individual cranial samples. Three of the individual sample populations display no significant sexual dimorphism in the expression of nonmetric traits and the remaining three samples contain between one and three significant sex differences. Two of these population samples, Developed Krotovo (Locality 1) and Late Krotovo, display percentages of significant sex difference that exceed the number of traits that would be expected to differ by chance alone.

Table 3.3 also presents the sex affected traits for each sample as well as their associated trait categories. The majority of observed sex differences can be explained by the hyperostotic/hypostotic model, the single exception being a higher incidence of *lingula bridge (trait 14)* among the Developed Krotovo (Locality 1) Female sample. In addition, only one of the four traits displaying significant sex differences in the pooled sample of Siberian crania is represented among the sex affected traits of the individual population samples. This trait, *foramen spinosum open (trait 20)*, is examined for directional bias in the following chart which lists the number of times a significant difference in male versus female trait expression was observed across the six Siberian cranial samples.

Trait	Sex Preference	Higher Male	Higher Female	No Difference
Foramen Spinosum Open	Female	0	1	5

An examination of the results suggests the presence of a weak directional bias in a single population sample supporting the hyperostotic/hypostotic model of sex difference for *foramen spinosum open (trait 20)*. Fortunately, the majority of the samples do not

Table 3.3 - Results of Test for Sex Differences in Nonmetric Trait Incidence for the Siberian Cranial Samples

Cranial Samples	Number of Traits Displaying Significant Sex Differences in Trait Freq*	%	Traits	Trait Category	Sex with Highest Freq
Pooled Cranial Sample	4/35	11.43	PterSBr	Hyperostotic	Male
			ForSpinOp	Hypostotic	Female
			SagSutOs	Sutural Ossicle	Male
			RockJaw	Unclassified	Female
Eneolithic	0/33	0.00	-	-	-
Developed Krotovo (Locality 1)	3/33	9.09	PterABr	Hyperostotic	Male
			LingBri	Hyperostotic	Female
			ForSpinOp	Hypostotic	Female
Developed Krotovo (Locality 2) Without Kurgan	1/33	3.03	MylohA	Hyperostotic	Male
Developed Krotovo (Locality 2) With Kurgan	0/30	0.00	-	-	-
Late Krotovo	3/31	9.68	TympDeh	Hypostotic	Female
			AccInfOFor	Foraminal	Male
			CondFacDo	Unclassified	Male
Andronovo	0/27	0.00	-	-	-

Legend: *- number of traits significant at the 5% level out of the total number of traits with data values permitting the calculation of the chi-squared statistic.

display similarly significant gender differences in the expression of this trait and, thus, its inclusion within the following analysis is not likely to significantly distort biological distance coefficients between pairwise samples.

3.2 Side and Symmetry Differences

The present section examines several distributional aspects of the Siberian nonmetric data concerning side differences and symmetry in nonmetric trait expression. The first consideration is a test for side to side dependence of the bilateral nonmetric traits. This test measures the propensity of a bilateral variant to be expressed as present, *or absent*, on both sides of an individual. The sexes were pooled for each of the population samples and those crania where bilateral trait expression was not observable were excluded. The investigation of side to side dependence in the present study was facilitated by arranging the data in a two-by-two contingency table and using the chi-squared statistic presented by Green and coworkers (1979). The data are arranged as shown below:

		Right side	
		Present	Absent
Left	Present	a	c
side	Absent	b	d

The chi-squared test statistic is

$$X^2 = \frac{n(ad-bc)^2}{(a+b)(a+c)(b+d)(c+d)}$$

where n = a + b + c + d, the number of crania for which the trait can be scored on both sides. The application of the standard Pearson's chi-squared test, Yate's Correction for Continuity or Fisher's Exact Test followed Thomas' (1976:298) guidelines as outlined in section 3.1 above.

The side and symmetry data and the results of a test for side to side dependence in bilateral trait expression for 27 nonmetric variants are presented in Appendix D, beginning with the data for a pooled sample of the Siberian crania and followed by the data for each of the six individual cranial samples. In addition to the above chi-squared test, sample phi correlations and coefficients of determination (r^2) were calculated for

each of the bilateral variants using the formula:

$$\phi = \left[\frac{(ad - bc)^2}{(a+b)(a+c)(b+d)(c+d)} \right]^{1/2}$$

In the pooled sample, the majority of traits display significant side interdependence at the 1% level (n=23) and display strongly positive, although not perfect (*i.e.,* where phi = 1), phi values that range from between -0.166 and 0.701. One bilateral variant, *pterygo-spinous bridge (partial) (trait 11)*, displays side to side interdependence just under the 5% level of significance and exhibits a similarly positive side correlation of 0.215. Three of the bilateral variants fall outside of the 5% significance level, suggesting a tendency towards unilateral expression for these traits in the pooled sample. Of these three traits, the *coronal sutural ossicle (trait 44)* displays the weakest propensity for side to side independence with a chi-square value falling just outside the 5% significance level and a positive phi value of 0.304. The remaining two traits, *accessory supraorbital foramina (trait 34)* and *occipitomastoid sutural ossicle (trait 48)* display a marked tendency for asymmetrical expression in the pooled sample with chi-squared values that fall well outside of the 5% significance level and phi values of 0.085 and -0.166, respectively.

An examination of the side to side dependence and side correlations for the six individual cranial samples reveals considerable variation from the general trends observed in the pooled sample. A comparison of the number of traits displaying side to side dependence and perfect side correlations in the pooled and individual cranial samples is presented in Table 3.4. The proportion of traits displaying significant side to side dependency is greatly reduced in the smaller individual cranial samples. The decreasing number of side to side correlations is likely due to the proportional increase in the variance of the observed correlations expected as sample sizes are reduced (Green *et al.* 1979). An interesting observation is the absence of perfect side correlations in all samples except the Late Krotovo and Andronovo population samples which represent the youngest culture-historical groups considered in this study.

The results of the analysis for side to side dependence and correlation in the Siberian cranial samples is in agreement with previous studies that have found highly significant interdependence and strongly positive correlations between the sides (Green *et al.* 1979; Molto 1983:134; Saunders 1978:82). As reported earlier, positive side to side correlations support the use of the 'individual' scoring method, since scoring of bilateral

Table 3.4 - Results of Side and Symmetry Tests of Bilateral Nonmetric Variation in the Siberian Cranial Samples

Cranial Samples	Number of Traits Displaying Significant Side to Side Dependence*	%	Number of Traits Displaying Perfect Side Correlation*	%	Number of Traits Displaying Significant Side Differences in Trait Freq*	%	Mean Index of Bilaterality
Pooled Cranial Sample	24/27	88.89	0/27	0.00	2/27	7.41	37.22
Eneolithic	11/25	44.00	0/25	0.00	2/26	7.69	37.66
Developed Krotovo (Locality 1)	11/23	47.83	0/23	0.00	0/26	0.00	29.09
Developed Krotovo (Locality 2) Without Kurgans	9/20	45.00	0/20	0.00	1/23	4.35	34.22
Developed Krotovo (Locality 2) With Kurgans	13/23	56.52	0/23	0.00	1/24	4.17	42.76
Late Krotovo	13/23	56.52	3/23	13.04	2/26	7.69	44.76
Andronovo	2/18	11.11	4/18	22.22	0/23	0.00	43.86

<u>Legend:</u> *- number of traits significant at the 5% level or showing perfect side correlation out of the total number of traits with data values permitting the calculation of the associated statistic.

variants by the 'side' method would lead to the introduction of redundant information and an overestimation of genetic causality in biological distance coefficients. However, a general misconception in the interpretation of side interdependence statistics was revealed by Molto's (1983:138-139) observation that these statistics are heavily weighted by the commonly observed 'absent' category towards perfect side correlation. To examine the actual prevalence of unilaterality versus bilaterality in sample populations, Molto (1983:137) has introduced the index of bilaterality that is calculated using the formula

$$\text{Index of Bilaterality} = \frac{\text{frequency of bilateral presence (a)}}{\text{frequency of unilateral presence ((b+c) + a)}} \times 100$$

where a value of 50 represents an equal proportion of unilateral versus bilateral expression and values of 0 and 100 represent total unilateral and total bilateral occurrence, respectively.

Appendix D presents the index of bilaterality values for the separate and pooled Siberian cranial samples. An examination of the pooled sample reveals a greater tendency towards unilateral expression of bilateral variants since only 6 traits (22%) express an index value greater than 50. In addition, asymmetric trait manifestations are expressed to a greater degree as demonstrated by the index of bilaterality values in the pooled sample that range from a low of 0.00 to a high of only 74.45. A comparison of the mean values of the index of bilaterality for the different trait categories in this sample demonstrates that sutural variants displays the greatest tendency for asymmetrical expression (mean=25.05), followed by the foraminal trait category (mean=37.70), the hypostotic variants (mean=39.33), and, finally, the hyperostotic traits (mean=40.70). It is therefore not surprising that the three traits displaying insignificant side to side correlation are all representatives of the sutural and foraminal variant categories and that they comprise 3 of the 4 lowest index of bilaterality values.

Table 3.4 presents a comparison of the mean index of bilaterality values for the separate cranial samples and the pooled sample. These mean values display considerable variation from sample to sample. The mean of the index of bilaterality values for the pooled sample of Siberian crania is 37.22. The mean index values for the Developed Krotovo (Locality 1) and Developed Krotovo (Locality 2) Without Kurgan samples lie below the mean value of the pooled sample while the values for the Developed Krotovo

(Locality 2) With Kurgan, Late Krotovo and Andronovo samples lie significantly above this value. The remaining Eneolithic sample differs only slightly from the mean value of the pooled sample. If Trinkaus's (1978) conviction that external environmental stresses significantly contribute to the occurrence of asymmetrical expression in humans, then the above deviations from the mean of the pooled sample may represent the differential ability of these populations to successfully buffer environmental stress during the period of active growth and development. This could be related to a multitude of factors associated with the biocultural systems of these populations including nutrition, the relative success of different economic strategies, status and differential access to resources, or divisions of labor with corresponding differences of biomechanical stress among the populations. Table 3.4 shows that the Krotovo pit interment burial grounds display Mean Index of Bilaterality values well under the mean of the pooled sample and the Krotovo kurgan burial grounds display values well above this mean. This result may indicate differential health and/or access to subsistence resources between these burial groups which may suggest that the Krotovo (Locality 2) With Kurgan and Late Krotovo burial grounds at the Sopka-II site represent cemeteries reserved for high status members of the local population.

An important consideration when employing the 'side' method of scoring, distinct from measuring the side to side dependence of bilateral variants, is the examination of side differences in trait incidence. If significant asymmetry in trait incidence between the sides is noted for a bilateral variant it should be excluded from the trait list before the calculation of biological distance coefficients. Green and coworkers (1979) present a chi-squared test that measures whether the probability of occurrence of a trait is the same on each side which is calculated as follows:

$$X^2 = \frac{(b-c)^2}{b+c}$$

Appendix D presents the results of this test for both the pooled sample of Siberian crania and the individual samples. Only two traits in the pooled sample display side differences in trait incidence at the 5% significance level. This is only slightly greater than the number of traits that would be expected to significantly differ by chance alone. In addition, none of the three traits display 5% significance level in any of the individual cranial samples, further supporting an interpretation of these side differences as chance

occurrences. Table 3.4 presents the number of variants displaying significant side differences in trait incidence for both the pooled sample and the individual cranial samples. All of the samples display side differences that are under or only slightly greater than the number of traits expected to significantly differ by chance alone. In addition, none of the traits differ significantly in side to side trait incidence across more than one sample. Given the highly arbitrary pattern of occurrence of side differences in trait incidence across the samples, it is unlikely that they represent biologically meaningful tendencies for the expression of nonmetric variants on one side more often than the other.

The results for tests of side to side dependence, bilaterality and side difference in trait incidence indicate that nonmetric variants in the Siberian crania display a propensity towards asymmetrical expression, that both sides of the body maintain similar threshold values for expression and that these unilateral manifestations have equal chances of occurring on the right or left sides. Taken together, these results provide a strong argument for advocating the 'side' method of scoring in the present study, especially considering the practice of including all adult crania and cranial fragments that were scorable for at least one trait, regardless of their preservational state. Further analysis of the nonmetric data will be based entirely upon the 'side' method of scoring.

4.0 SUMMARY

This chapter has presented the initial criteria guiding the selection of cranial nonmetric traits and has evaluated the consistency of the proposed scoring methods for each of these variants. A total of 36 of the original 52 traits display acceptable levels of intraobserver scoring consistency as presently defined. An examination of the distributional properties of the nonmetric data for significant differences in trait incidence has revealed no side or sex biases. Thus, the majority of these distributional differences are likely not biologically meaningful and, instead, are attributed to chance occurrence. An interesting result is the increased propensity for asymmetrical expression within the Krotovo pit inhumation burial grounds as opposed to the Krotovo kurgan burial grounds. This may represent a distinction between these synchronic burial groups that is related to status distinctions within the local population. It is necessary to state that the results and

general conclusion of the intraobserver scoring consistency, side difference and sex difference tests are relevant only to skeletal populations from the study area and should not be generalized to skeletal samples from other regions or periods. In summary, the selected trait list of 36 nonmetric variants will be utilized in the following biological distance analysis.

CHAPTER 4: THE BIOLOGICAL DISTANCE ANALYSIS

The analysis of nonmetric biological distance between the Eneolithic and Developed Bronze Age cranial samples will utilize a multivariate biostatistical approach. The purpose of this approach is to report meaningful biological interrelationships from the morphological patterning of nonmetric expression observed in the Siberian skeletal series. The employed multivariate statistic is C.A.B. Smith's Mean Measure of Divergence (Grewal 1962; Berry and Berry 1967; Sjøvold 1973). This statistic identifies similarity or dissimilarity between separate skeletal samples by simultaneously examining differences in trait incidence across a series of discrete variants. The effectiveness of the approach relies upon two important assumptions: that the skeletal samples represent, as closely as possible, living human populations; and, that the expression of nonmetric variants is predominantly under genetic control. Regarding the first assumption, Cadien *et al.* (1974) have suggested that skeletal biological distance studies are compromised by the possibility that burial populations represent samples of human lineages rather than human demes. The present author recognizes the potential theoretical limitations of using human burial groups as population samples. However, it should be stressed that burial grounds are rarely encountered with superior chronological, spatial and culture-historical controls for delineating prehistoric burial groups than at Sopka-II. Formulation of the skeletal samples has followed Molodin's (1985, 1995a,c) interpretation of spatially discrete burial areas at the Sopka-II site and his designation of these to discrete culture-historical periods on the basis of mortuary ritual and burial inventory. The relative chronological sequence of the samples has been established on the basis of both radiocarbon and relative dating methods. Regarding the latter assumption, it is well established that environmental, developmental and physiological factors play a significant role in the expression of certain nonmetric traits. For this reason, this study has adopted a 'reductionist' approach and has employed several selective procedures in creating the final trait list in order to exclude nonmetric variants which were inconsistently scored or whose expression are largely determined by nongenetic factors.

The next section presents a brief description of the method and theory of biological distance analysis and the employed Mean Measure of Divergence (MMD) statistic. This background section is followed by a nonmetric biological distance analysis of synchronic

burial populations belonging to the Krotovo culture. These cranial series comprise the main portion of the present sample. The biological differentiation manifest within the Krotovo skeletal series and the relationship of these population samples to previous and future inhabitants of the region is explored by a second biological distance analysis that includes the temporally distinct Eneolithic and Andronovo samples.

1.0 THE MEAN MEASURE OF DIVERGENCE: THEORY AND METHOD

Physical anthropologists have long recognized the utility of multivariate distance statistics for assessing affinity or divergence between population samples based upon large numbers of qualitative skeletal traits (*cf.*, Molto 1983:13-18; Sjøvold 1977b:1-3). C.A.B. Smith's Mean Measure of Divergence (MMD) is currently one of the most widely used multivariate distance coefficients designed for the examination of qualitative morphological data (Sjøvold 1977b). Grewal (1962) was the first to introduce this statistic to the scientific community but its popularity in anthropological circles was established only after its use in the seminal publication by Berry and Berry (1967) on human nonmetric variation. The MMD simultaneously considers the variability expressed across a series of nonmetric traits between respective samples and reduces this information to a single biological distance value. This value contains the desired property that when population samples are similar the value of the statistic is small and when population samples are dissimilar the value is large.

The MMD differs from other types of distance coefficients in that its calculation first employs an angular transformation, measured in radians, of the original proportions of the traits being compared. The transformation is performed in order to stabilize the variance of the population sample which, in essence, is to make the transformed proportion independent of its variance (Sjøvold 1977b:7). This is necessary for nonmetric traits, whose occurrence follows the binomial distribution, since the variance of the sample proportion (p) is a direct function of the population proportion (P) as

demonstrated below:

$$\text{variance of (p)} = \frac{P\,(1 - P)}{n}$$

where (n) denotes the number of observations. An undesirable aspect of this relationship is encountered when comparing population frequencies with different variances since a weighting is introduced which is inversely proportional to the size of the variance (Sjøvold 1977b). The object of nonmetric biological distance studies is to examine changes in parent population proportions (P) by comparing the differences between sample proportions (p) which are assumed to be the best possible estimate of (P) (Sjøvold 1973). Thus, in order to study changes in the population proportion (P) without simultaneously changing the variance and introducing weighted biases to the compared traits, it is necessary to transform the sample proportion (p) to a new variable in which the sampling variance is independent of the population proportion (P) (Sjøvold 1977b). The angular transformation performs this function since the variance of the new variable, denoted theta (θ), is related solely to the inverse number of observations made for the trait (Sjøvold 1973). This is shown below where (n) denotes the number of observations:

$$\text{variance of } (\theta) = \frac{1}{n}$$

Thus, as stated by Sjøvold (1973:209), the result of the angular transformation is that "the variance of all variants investigated depend on the number of individuals in the population sample and not on the proportions in the total population from which the sample is taken. This means that the mean measure of divergence has the property that all variants investigated are equally important when based upon the same number of observations".

A number of angular transformations have been proposed for use in calculating the Mean Measure of Divergence (*cf.*, Green & Suchey 1976; Sjøvold 1973, 1977b). Common to all methods is that variance stabilization becomes more effective as sample sizes increase and as the population proportion (P) for a particular trait approaches 0.5 (Sjøvold 1977b). Green and Suchey (1976) have compared the relative effectiveness of these transformations on samples of different sizes and at different values of (P). They recommend the Freeman and Tukey arcsine transformation since, for small sample sizes,

it stabilizes the variance best. Trait proportions in the present study were transformed using the Freeman and Tukey method which is calculated as follows:

$$\Theta = \frac{1}{2} \sin^{-1} \left[1 - 2 \frac{k}{n+1} \right] + \frac{1}{2} \sin^{-1} \left[1 - 2 \left[\frac{k+1}{n+1} \right] \right]$$

where k = the observed incidence of the trait, and n = the number of observations for the trait.

A Measure of Divergence (MD) was calculated for each pairwise variant by squaring the difference between the theta (θ) values for each population and subtracting the sum of the assumed variance. Thus, the Mean Measure of Divergence (MMD) is obtained by summing the separate Measures of Divergence between corresponding variates of the two populations and dividing by the number of variants considered. The mathematical method of Sjøvold (1973), with the modifications suggested by Green & Suchey (1976), is followed for calculating the MMD as shown below:

$$MMD = \frac{\sum_{i=1}^{r} \left[[\theta_{1i} - \theta_{2i}]^2 - \left[\frac{1}{n_{1i} + {}^1/_2} + \frac{1}{n_{2i} + {}^1/_2} \right] \right]}{r}$$

where $\theta_{1i.}$ θ_{2i} = the angular transformation in radians of the ith trait for samples 1 and 2, respectively ; n_{1i}, n_{2i} = the actual number of observations for the ith trait for samples 1 and 2, respectively; and r = the number of traits. The assumed variance of $(\theta_{1i} - \theta_{2i})$ when using the Freeman and Tukey transformation is represented not by $(1 / n_{1i} + 1 / n_{2i})$ but by the expression $(1 / (n_{1i} + {}^1/_2) + 1 / (n_{2i} + {}^1/_2))$. Subtracting this value from the squared theta value removes the variance resulting from random sampling fluctuations resulting in an estimate of divergence that reflects only the parent population parameters (P) (Sjøvold 1977b).

Methods for testing the significance of an MMD estimate rely upon the relationship that exists between the distribution of this statistic and the chi-squared normal distribution (Berry 1963; Sjøvold 1973, 1977b). This relationship follows from the convergence theory of Liapounoff (*cf.*, Sjøvold 1977b:30) with the result that, assuming trait independence, the MMD is approximately distributed according to the normal

distribution with zero mean under the null hypothesis and variance calculated as shown below:

$$\mathrm{Var}_{MMD} = \frac{2}{r^2} \sum_{i=1}^{r} \left[\frac{1}{n_{1i} + 1/2} + \frac{1}{n_{2i} + 1/2} \right]^2$$

Thus, as Sjøvold (1977b) notes, testing the MMD for significance is essentially a test of the equality of the population proportions which is in concordance with the null hypothesis of the chi-squared distribution. Given this relationship, Sjøvold (1973, 1977b) has devised a simple 'normal approximation test' whereby the MMD is considered significant at approximately the 5% level when larger than twice its standard deviation, given by the square root of the variance. Thus, the quotient of the 'normal approximation test', denoted the standardized MMD, is significant at the 5% level when its value is 2.0 or greater. It is more appropriate to consider the standardized MMD rather than the MMD in population comparisons between samples of unequal size (Johnson & Lovell 1994; Sofaer *et al.* 1986). Sjøvold (1977b) warns that a non-significant result need not imply that the two samples derive from the same population but only that the two parent populations are indistinguishable based upon the available data. It must be determined for each particular case whether this situation is the result of actual biological affinity between the population samples, insufficiently small sample sizes or the use of an indiscriminant set of nonmetric traits. Sjøvold (1973) further warns that definitive conclusions concerning population affinity or divergence should be reserved when the standardized MMD value is close to its critical level (*i.e.,* standardized MMD = 2.0).

The decision of which variables to include within a population comparison is a critical factor contributing to the probability that the resultant MMD estimates will be significant. On the one hand, it is desirable to base an investigation on as many variants and as large a sample as possible in order to reduce the standard deviation of the MMD estimate and to maximize the amount of 'morphogenetic' information represented by the distance coefficient (Sjøvold 1973). However, Sjøvold (1977b) warns that the inclusion of indiscriminant traits tends to dilute the significance of MMD estimates. He recommends that trait selection include only those variants that best discriminate between population samples. Thus, it is initially important to examine the variability of each

nonmetric trait on a univariate basis so that those variants displaying little or no variation between the samples can be excluded from consideration in the MMD.

Unfortunately, no standardized method exists for determining the appropriate level of variability required for the inclusion of a trait within a population comparison. Some researchers (*i.e.*, Buikstra 1976) require only that a variant perform as a real variable in at least two of the samples tested regardless of the significance of the difference. This method serves to exclude 'dummy variants' from population comparisons which Sjøvold (1973) describes as discrete variables that are either always present or always absent in all populations compared. At the other end of the spectrum, some authors (*i.e.*, Molto 1983; Sjøvold 1977b) require that variants display a significant difference at the 5% level between at least two samples included in a population comparison. This method excludes both 'dummy variants' and traits that are rarely expressed across the population samples under investigation. In a later paper, however, Sjøvold (1986) suggests that traits found to significantly vary at the 10% level of significance between at least two populations be included within MMD estimates in order to incorporate as much variation as possible while simultaneously keeping the standard deviation of the distance estimates at a low level.

This study will calculate and examine two biological distance estimates for each population comparison: one derived from traits displaying variability up to the 10% level of significance; and, another from traits found to vary up to the 20% level of significance. The reason for examining two MMDs for each comparison is to observe the effects of including lower variability traits on the resultant distance estimates. Traits displaying lower overall variation and higher levels of significance are excluded from further consideration since they are considered to poorly discriminate between the samples and would dilute the resultant MMD estimates.

Interpretation of the MMD matrices between the samples is facilitated by three methods. The first method, devised by Sjøvold (1973), involves the simple comparison of standardized MMD estimates between successive groups of three samples. This intuitive method assists not only in interpreting the geometric relationships between samples but also the relative direction of the population divergence by examining whether or not the 'triangular inequality' is satisfied. The 'triangular inequality' holds when the sum of the distances between one sample and an intermediate sample and

between this intermediate sample and another sample is greater than or equal to the distance estimate measured between the first and the last samples. The implication is that when equality exists, the three populations points are situated on a line along which the distance is measured (Sjøvold 1977b) from which a strong argument for the samples representing an evolutionary continuum can be forwarded. A number of microevolutionary processes such as mutational events, gene flow, genetic drift or founder effect may alter the evolutionary divergence in one or another direction. Forwarding direct microevolutionary interpretations of MMD matrices, however, is complicated by the fact that distance estimates are products of squared differences between two arcs and, therefore, are not representative of a linear space but of a curved space, the surface of a sphere (Sjøvold 1977b). Thus, the MMD estimates are not governed by the principles of Euclidean geometry in the strict sense. However, as stated by Sjøvold (1977b:24) "... when the divergence between the population is not very large, the surface of the sphere is fairly plane, and the distances between two points representing two populations approximately Euclidean. When the divergence increases, the Euclidean geometry cannot longer be applied ...".

The second interpretive method involves the calculation of a Measure of Uniqueness for each of the samples represented in the distance matrix. This statistic is calculated by the simple summation of all standardized MMD estimates for one sample across a distance matrix (Sjøvold 1977b). The resultant value represents the distinctiveness of each population sample relative to the other samples with higher values denoting an increasingly distinctive cranial sample.

The final method used to interpret the MMD matrices is cluster analysis. This taxonomic technique is useful in examining morphological relationships across large MMD matrices. More specifically, Ward's Error Sum of Squares method (Ward 1963) is employed. This clustering method is both hierarchical, in that it constructs dendrograms displaying the relationships between population samples, and agglomerative, in that it uses an algorithmic function to construct dendrograms from the separate objects (*i.e.*, population samples) to the root of the tree (Molto 1983:191). Ward's method is best known as the minimum variance method since it generates clusters on the basis of the minimum distance of each item in a cluster from the mean of that cluster. In a

comparison of various cluster methods, Blashfield (1976) found Ward's method consistently superior in deriving clusters that represented the known, true classification.

2.0 THE SYNCHRONIC BIOLOGICAL DISTANCE ANALYSIS

The purpose of this section is to evaluate and compare the cranial nonmetric variation displayed between four Sopka-II burial populations belonging to the Krotovo culture. The sample names will be presented in their full form and italicized in the text. However, in the interest of clarity, the designation 'Developed' will be excluded since all Krotovo samples represent Developed Bronze Age populations. In addition, the following abbreviations are used to refer to the samples in several tables and figures:

Abbreviations		Population Samples
Dkroto (Locality 1)	⇒	Developed Krotovo (Locality 1)
Knokurg (Locality 2)	⇒	Developed Krotovo (Locality 2) Without Kurgan
Kwkurg (Locality 2)	⇒	Developed Krotovo (Locality 2) With Kurgan
Lkroto	⇒	Late Krotovo
Andro	⇒	Andronovo
Eneo	⇒	Eneolithic

The skeletal samples belonging to the Krotovo culture-historical epoch were excavated from three distinct burial grounds at the Sopka-II site. These populations are thought to represent an intensive and relatively synchronic occupation of the site (Molodin 1995a) and comprise 71.4% (n = 220) of the total skeletal series examined in the present study. A consideration of the prehistory of the Krotovo culture in the Barabinsk forest-steppe (*cf.*, Chapter 1, Section 3.0) and of specific characteristics (*i.e.*, mortuary ritual, burial inventory, spatial analysis) of the Krotovo burial grounds at Sopka-II (*cf.*, Chapter 2) has led to a series of hypotheses regarding the biological relationships between these populations:

1. 'Chronological hypothesis'. Assuming that microevolutionary change occurs consistently over time in a population inhabiting the same region, those burial populations belonging to the same period should display more biological similarity than temporally distinct samples. Thus, the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* samples should display more biological affinity to each other than to the *Late Krotovo* sample which represents a slightly later phase of occupation at the Sopka-II site on the basis

of radiocarbon dates as well as typological characteristics of the burial assemblages (Molodin 1995a). No radiocarbon dates were obtained for the *Krotovo (Locality 2) With Kurgan* sample but Molodin (1995a) associates this burial ground with the *Krotovo (Locality 2) Without Kurgan* skeletal series on the basis of spatial and typological similarities, despite observed differences in mortuary ritual.

2. 'Spatial hypothesis'. According to this hypothesis, biologically related individuals are expected to be interred more closely together than would unrelated individuals. Two major burial clusters can be identified in the Krotovo burials at the Sopka-II site (*cf.*, Maps 1 and 2). One cluster is represented by the *Krotovo (Locality 2) Without Kurgan*, *Krotovo (Locality 2) With Kurgan* and *Late Kroto*vo burial grounds which is characterized by a linear row of pit and kurgan interments situated along the eastern embankment of the Sopka-II site. Spatial variability exists within this large cluster. The spatial discreteness of these burials decrease from the south to the north and the presence of pit interments not related to kurgan structures increases in the same direction. The second cluster is represented by the *Krotovo (Locality 1)* burial ground which consists of a discrete cluster of graves located along the western margin of the excavated area at the Sopka-II site.

3. 'Culture-historical hypothesis'. This hypothesis is based upon the assumption that mortuary ritual and material culture are normative attributes of human culture that are conservative to change through time. Thus, one would expect a tendency for continuity in the mortuary ritual and forms of material culture between biologically related individuals from generation to generation. It has been previously stated that mortuary ritual is likely more conservative to change than material culture attributes. Given these assumptions, the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* samples should display more biological similarity to each other than to the two remaining Krotovo burial grounds that display kurgan mortuary structures. Alternatively, the *Krotovo (Locality 2) With Kurgan* and *Late Krotovo* samples should be more similar to each other than to the other Krotovo burial grounds that display simple pit interments. However, Molodin (1995a) has recognized typological

differences in the grave good assemblage of these kurgan burial groups which suggest that the *Late Krotovo* burial ground is dated to a slightly later period than the *Krotovo (Locality 2) With Kurgan* sample. This presents the possibility of associated biological differentiation between the two Krotovo kurgan burial grounds. In addition, this hypothesis would predict that Krotovo cranial samples at the Sopka-II site should display closer biological affinity to each other than to the earlier *Eneolithic* and later *Andronovo* samples.

4. 'Social stratification hypothesis'. The assumption that mortuary ritual and material culture represent normative attributes of culture during the Krotovo period is complicated by the increasing social stratification identified by the appearance of labour intensive kurgan burials at the Sopka-II site. It is conceivable that the kurgan burial populations represent a high status substratum of the local Krotovo population or an elite group that is intrusive to the region. If differences in mortuary ritual are related to the social stratification of Krotovo populations using Sopka-II, one would expect associated biological differentiation between the Krotovo kurgan and non-kurgan cranial samples.

5. 'Migration hypothesis'. The placement of the synchronic Krotovo occupation of the site during the latest phases of this culture and the subsequent appearance of kurgan burials and Andronovo cultural elements within the Krotovo burial grounds suggests intensive contact with culture areas to the west and to the southwest (Molodin 1995a,c). Considering the magnitude of this change and the eventual replacement of the Krotovo culture by the Andronovo cultural tradition in the Baraba region, one should expect the simultaneous migration of Andronovo populations.

The following analysis will examine whether these hypotheses are supported by the nonmetric distance data.

The results of a univariate variance analysis on 36 nonmetric traits between the four Krotovo cranial samples is presented in Table 4.1. The intent of this analysis is to identify those nonmetric traits of most taxonomical significance for discriminating between the Krotovo cranial samples. Following Sjøvold (1977b), a simple chi-squared

test based upon the observed, untransformed proportions was used to test the significance of trait variability between the two most divergent population samples (*cf.*, Table 4.1). The application of the standard Pearson's chi-squared test, Yate's Correction for Continuity or Fisher's Exact Test followed Thomas' (1976:298) guidelines as outlined in Chapter 3 (*cf.*, Section 3.1). Only one of the 36 traits, *bregmatic bone (Trait 43)*, is not expressed in any of the Krotovo population comparisons. This 'dummy variant' is excluded from further consideration in the calculation of MMD values. The remaining 35 traits are sorted in increasing order by the chi-squared level of significance (p). The difference between the highest and lowest proportions for each variant across the Krotovo samples is highly variable, ranging from 0% to 31%. Nine of the 35 traits (25%) display a difference between high and low samples that is significant at the 5% level.

Table 4.1. Results of variability analysis on 36 nonmetric traits between four Krotovo cranial samples sorted in increasing order by the chi-squared level of significance. The single and double lines indicate cut-off points at the 10% and 20% significance levels, respectively.

Nonmetric Traits	Range of Trait Frequencies: Low n	Low N	Low Freq	Cranial Sample	High n	High N	High Freq	Cranial Sample	Frequency Difference	Chi-square Freq Diff	p
51 CondFacDo	7	64	0.11	Knokurg	23	55	0.42	LKroto	0.31	14.961	0.000†
37 AccInfOFor	6	42	0.14	Kwkurg	34	76	0.45	DKroto	0.31	11.194	0.001†
3 PrecondTub	13	114	0.11	DKroto	17	54	0.31	Kwkurg	0.20	8.748*	0.003†
52 RockJaw	18	65	0.28	DKroto	17	30	0.57	LKroto	0.29	7.406	0.007†
10 PterABr	6	57	0.11	LKroto	14	50	0.28	Kwkurg	0.17	4.263*	0.039†
12 TrochSpur	3	133	0.02	DKroto	7	71	0.10	Kwkurg	0.08	4.226*	0.040†
25 ParFor	49	72	0.68	LKroto	76	93	0.82	Knokurg	0.14	4.126	0.042†
18 TympDeh	5	69	0.07	Kwkurg	14	69	0.20	LKroto	0.13	3.906*	0.048†
8 IntCondCan	14	46	0.30	LKroto	26	52	0.50	Kwkurg	0.20	3.868	0.049†
11 PterSBr	1	48	0.02	Knokurg	8	55	0.15	LKroto	0.13	3.551*	0.060
42 OsAst	3	68	0.04	Knokurg	9	56	0.16	LKroto	0.12	3.536*	0.060
9 AntCondCan	9	59	0.15	LKroto	17	60	0.28	Kwkurg	0.13	2.980	0.084
4 OsApiLig	1	28	0.04	LKroto	7	34	0.21	Knokurg	0.17	2.587*	0.108
14 LingBri	32	59	0.54	LKroto	48	72	0.67	Knokurg	0.13	2.107	0.147
20 ForSpinOp	15	51	0.29	Kwkurg	24	56	0.43	LKroto	0.14	2.083	0.149
34 AccSupOFor	1	72	0.01	LKroto	5	67	0.07	Kwkurg	0.06	1.804*	0.179
13 MylohA	6	110	0.05	DKroto	9	75	0.12	Knokurg	0.07	1.761*	0.185
41 LambSutOs	31	103	0.30	DKroto	24	60	0.40	Kwkurg	0.10	1.663	0.197
2 MargFor	18	130	0.14	DKroto	13	65	0.20	LKroto	0.06	1.227	0.268
39 OsLam	0	34	0.00	Kwkurg	3	41	0.07	Knokurg	0.07	1.036*	0.309
46 EpiBone	5	58	0.09	DKroto	6	33	0.18	Kwkurg	0.09	1.022*	0.312
5 ClinoCBri	1	39	0.03	Knokurg	5	50	0.10	Kwkurg	0.07	0.926*	0.336
40 IncaB	0	55	0.00	DKroto	2	42	0.05	Knokurg	0.05	0.836*	0.361
21 OsJap	3	41	0.07	Knokurg	12	83	0.14	DKroto	0.07	0.730*	0.393
45 SagSutOs	0	32	0.00	Knokurg	2	28	0.07	LKroto	0.07	0.667*	0.414
32 SupOrbFor	13	141	0.09	DKroto	12	97	0.12	Knokurg	0.03	0.607	0.436
19 ForOvInc	1	59	0.02	Knokurg	3	48	0.06	Kwkurg	0.04	0.523*	0.470
28 ParProcT	0	59	0.00	Kwkurg	2	63	0.03	LKroto	0.03	0.444*	0.505
27 SSSTR	26	36	0.72	Kwkurg	46	58	0.79	DKroto	0.07	0.290*	0.590
44 CorSutOs	0	57	0.00	Kwkurg	2	75	0.03	Knokurg	0.03	0.274*	0.601
22 Metop	0	51	0.00	Knokurg	2	69	0.03	DKroto	0.03	0.255*	0.614
48 OcMastSutOs	2	44	0.05	Knokurg	4	42	0.10	Kwkurg	0.05	0.233*	0.630
31 ZygFacFor	8	51	0.16	Kwkurg	13	62	0.21	Knokurg	0.05	0.226*	0.635
50 FroTempArt	0	80	0.00	DKroto	1	48	0.02	LKroto	0.02	0.067*	0.796
24 GenPit	60	61	0.98	DKroto	27	27	1.00	Kwkurg	0.02	0.000*	1.000
43 BregBone	-	-	0.00	-	-	-	0.00	-	0.00	Dummy Variable	

Legend: * - Yate's Correction for Continuity; † - significant at the 5 % level

Based upon the results of this analysis, two separate MMD matrices will be calculated for the purpose of population comparison between the Krotovo samples. The first population comparison is based upon nonmetric traits displaying variation up to the 10% level of significance (n = 12; *cf.*, single line cut-off in Table 4.1). The second population comparison is based upon nonmetric traits found to vary up to the 20% level of significance (n = 18; *cf.*, double line cut-off in Table 4.1). Thus, a maximum of 18 nonmetric traits will be used to evaluate and compare the biological distance between the Krotovo samples. This reduced trait list represents just over one half (51.4%) of the 35 nonmetric traits considered in the univariate variance analysis.

The composition of this reduced trait list in regards to Ossenberg's (1969) trait classification scheme presented in Chapter 3 reveals that exactly one half of the 18 nonmetric variants (n = 9) belong to the 'hyperostotic' trait category. The remaining 50% of the traits are relatively evenly divided between the 'hypostotic', 'the foramina, canals and grooves', 'the accessory sutural ossicles and sutural variations', and the 'unclassified' trait categories. Thus, hyperostotic traits are found to be of greatest taxonomical significance for differentiating between the Krotovo samples from the Sopka-II site.

The MMD coefficients between the Krotovo samples based upon 12 nonmetric traits (*i.e.*, variable at the 10% level of significance) are presented in Table 4.2. Five of the six population comparisons display significance at the 5% level suggesting considerable biological diversity among the samples. However, this result is expected since only the most discriminating traits are considered. It is interesting to note that all of the significant distance coefficients involve a comparison with or between the Krotovo kurgan burial groups represented at the Sopka-II site (*i.e., Krotovo (Locality 2) With Kurgan* and *Late Krotovo* cranial samples). The distinctiveness of these samples is corroborated by their high Measures of Uniqueness in relation to the population samples from the Krotovo pit interment burial grounds (*i.e., Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* cranial samples). A standardized MMD value of 4.9202, the second highest in the matrix, also reveals considerable biological differentiation between the *Late Krotovo* and *Krotovo (Locality 2) With Kurgan* cranial samples, both excavated from kurgan burial grounds at the site. Another important result is the lack of significance of the MMD estimate between the *Krotovo (Locality 1)* and *Krotovo*

Table 4.2. Mean Measure of Divergence coefficients between Krotovo cranial samples using 12 nonmetric traits. The upper right triangular half lists the MMD distances and corresponding standard deviations in brackets. The lower left half presents the standardized MMD values for these comparisons. The Measure of Uniqueness for each sample is provided in the far right-hand column.

	Developed Krotovo (Locality 1)	Developed Krotovo (Locality 2) Without Kurgans	Developed Krotovo (Locality 2) With Kurgans	Late Krotovo	Measure of Uniqueness
Developed Krotovo (Locality 1)	-	0.0190 (0.0112)	0.0831 (0.0125)†	0.0426 (0.0122)†	11.8362 [3]
Developed Krotovo (Locality 2) Without Kurgans	1.6964	-	0.0423 (0.0154)†	0.0620 (0.0150)†	8.5765 [4]
Developed Krotovo (Locality 2) With Kurgans	6.6480†	2.7468†	-	0.0802 (0.0163)†	14.3150 [1]
Late Krotovo	3.4918†	4.1333†	4.9202†	-	12.5453 [2]

Legend: † - significant at the 5 % level; [1,2...] - designates the rank order of Measures of Uniqueness from largest to smallest.

Table 4.3. Mean Measure of Divergence coefficients between Krotovo cranial samples using 18 nonmetric traits. The upper right triangular half lists the MMD distances and corresponding standard deviations in brackets. The lower left half presents the standardized MMD values for these comparisons. The Measure of Uniqueness for each sample is provided in the far right-hand column.

	Developed Krotovo (Locality 1)	Developed Krotovo (Locality 2) Without Kurgans	Developed Krotovo (Locality 2) With Kurgans	Late Krotovo	Measure of Uniqueness
Developed Krotovo (Locality 1)	-	0.0118 (0.0092)	0.0524 (0.0105)†	0.0276 (0.0101)†	9.0058 [3]
Developed Krotovo (Locality 2) Without Kurgans	1.2826	-	0.0251 (0.0128)	0.0493 (0.0124)†	7.2193 [4]
Developed Krotovo (Locality 2) With Kurgans	4.9905†	1.9609	-	0.0606 (0.0137)†	11.3748 [1]
Late Krotovo	2.7327†	3.9758†	4.4234†	-	11.1319 [2]

Legend: † - significant at the 5 % level; [1,2] ... - designates the rank order of Measures of Uniqueness from largest to smallest.

(Locality 2)Without Kurgan samples especially since only the highest variability traits are considered in this population comparison.

MMD values between the four Krotovo samples calculated upon the basis of 18 traits (*i.e.*, variable at the 20% level of significance) are presented in Table 4.3. The use of a larger, more variable trait list has resulted in only four significant MMD estimates as opposed to five in the first MMD matrix. The standardized MMD value between the *Krotovo (Locality 2) Without Kurgan* and *Krotovo (Locality 2) With Kurgan* cranial samples now lies just below the significance cut-off at 1.9609. As predicted by the mathematical models of Sjøvold (1973, 1977b), the use of a larger, less variable trait list has diluted the resultant MMD values, reduced the standard deviation of these estimates, and has resulted in the observation of fewer significant differences between the population samples. However, the results from this MMD matrix sample a greater number of 'morphogenetic' traits among the Krotovo samples, and, presumably, represent the comparison of a larger number of genetic loci underlying nonmetric trait expression in the Siberian samples.

An examination of the pattern of variation between the first and second MMD comparisons reveals that the rank order of the distance estimates remains the same, with only the magnitude of the MMDs decreasing across the matrix with the addition of additional, less variable traits. Thus, the four significant MMD estimates still involve one of the two kurgan burial groups at Sopka-II and the distinctiveness of these populations is still supported by their high Measures of Uniqueness in relation to the other samples. In addition, considerable morphological differentiation is still displayed between samples from the kurgan burial grounds and the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* samples still display morphogenetic affinity. The concordance of the rank order of both the standardized MMD estimates and the Measures of Uniqueness for both MMD analyses suggests either that the direction of variability of the additional six traits is not contradictory to the more highly variable traits or that the contribution of these trait differences to the resultant MMD values is too small to affect the pattern of trait differences established with the smaller 12 trait list.

An examination of the MMD matrices for the Krotovo samples has revealed several interesting results. Of particular interest is the consistent morphogenetic similarity

displayed between samples from the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* burial grounds. Given the large number of crania represented by these samples and the demonstrated taxonomical value of the reduced trait list, the most plausible conclusion is that the MMD estimates between these samples represent true biological affinity and that the cranial samples derive from the same parent population. This conclusion is further supported by Molodin's (1995c) observation of similar mortuary ritual and grave goods between these burial grounds and the radiocarbon dates.

The *Krotovo (Locality 2) With Kurgan* and *Late Krotovo* cranial samples, excavated from kurgan burial grounds situated in a linear fashion along the eastern embankment of the Sopka-II site, display morphological dissimilarity with samples from both the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* pit interment burial grounds and also are distinct from each other. This latter finding discounts the hypothesis that Krotovo populations interred within mound burials should display closer biological affinity with each other than to individuals interred in the pit burial grounds. These results also support Molodin's (1995a) contention, and that of the radiocarbon dates, that the *Late Krotovo* burial ground represents a later phase of occupation of the Sopka-II site. Thus, the evaluation and assessment of the biological relationships between the kurgan burial groups and the remaining population samples must be performed separately.

The standardized MMD values between the *Krotovo (Locality 2) With Kurgan* and *Krotovo (Locality 1)* samples represent the most divergent distant coefficients in both population comparisons. By contrast, the standardized MMD values between the *Krotovo (Locality 2) With Kurgan* and *Krotovo (Locality 2) Without Kurgan* samples represent the second least divergent distance coefficients in both comparisons. The standardized MMD value for this comparison is significant in the 12 trait MMD matrix and just below the level of significance in the 18 trait MMD matrix. As noted by Sjøvold (1973), definite conclusions concerning morphological affinity or divergence between populations should be reserved when the resultant MMD value is close to its critical level. Without regarding significance, however, it can be concluded that the *Krotovo (Locality 2) Without Kurgan* sample is most closely related to the *Krotovo (Locality 2) With Kurgan* sample after the smaller MMD estimate between this sample and the *Krotovo (Locality 1)* series. On the surface, the relative morphological similarity of the

Krotovo (Locality 2) Without Kurgan sample to both the *Krotovo (Locality 1)* and *Krotovo (Locality 2) With Kurgan* samples, actually representing the two lowest distance coefficients within both MMD matrices, and the large divergence between the *Krotovo (Locality 1)* and *Krotovo (Locality 2) With Kurgan* samples suggest that the *Krotovo (Locality 2) Without Kurgan* sample may represent an intermediate population between these divergent samples. A test of the triangular inequality across the three samples assists with interpretation since if the *Krotovo (Locality 2) Without Kurgan* sample represents an evolutionary intermediary, then the sum of the standardized MMD estimates between itself and the *Krotovo (Locality 1)* and *Krotovo (Locality 2) With Kurgan* samples should be greater than or equal to the distance coefficient between the latter two samples. The reason for this is that the standardized MMD values between an early population and an intermediate and between the intermediate and a later population should, in theory, measure an equal or greater amount of morphogenetic information than would a direct MMD comparison between the early and late samples. An examination of the standardized MMD values (*cf.*, Tables 4.2 and 4.3), however, reveal that in neither population comparison is the triangular inequality satisfied for the three burial grounds when *Krotovo (Locality 2) Without Kurgan* is assumed to be intermediate.

It has been demonstrated that the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* samples share a similar pattern of nonmetric morphological expression. These findings, in conjunction with the observed similarities in mortuary ritual, grave goods and radiocarbon dates has led to the conclusion that these population samples display biological affinity. In addition, relative morphological similarity is demonstrated between the *Krotovo (Locality 2) Without Kurgan* crania and the *Krotovo (Locality 2) With Kurgan* sample. Since highly significant divergence is demonstrated between the *Krotovo (Locality 1)* and *Krotovo (Locality 2) With Kurgan* samples it appears that the *Krotovo (Locality 2) Without Kurgan* sample is heterogeneous by nature and shares patterns of morphological similarity with both the *Krotovo (Locality 1)* and *Krotovo (Locality 2) With Kurgan* samples along different sets of nonmetric variables. This would not be representative of a single evolutionary continuum between the three populations. The observed situation can be accounted for by genetic explanations. Assuming that the Locality 2 burial grounds can be assigned to a synchronous period of time, the greater similarity of the *Krotovo (Locality 2) Without Kurgan* and *Krotovo*

(Locality 2) With Kurgan samples could be the result of gene flow resulting from the migration of an intrusive population represented by the kurgan burial group and subsequent interbreeding with subgroups of the local *Krotovo (Locality 2) Without Kurgan* population. This interpretation would account for the heterogeneous morphological characteristics expressed by the *Krotovo (Locality 2) Without Kurgan* population. An alternative, and equally plausible, interpretation is the genetic isolation of a segment of the *Krotovo (Locality 2) Without Kurgan* population (*i.e.*, genetic drift) as a result of internal cultural processes such as increasing social stratification and resultant class endogamy and the subsequent development of this group into the *Krotovo (Locality 2) With Kurgan* population. Both of these genetic interpretation would be supported by the novel appearance of the status kurgan mode of interment during this time. The possibility of a third, non-genetic interpretation has been identified on the basis of spatial characteristics within the Locality 2 burial ground. A portion of the *Krotovo (Locality 2) Without Kurgan* population sample may in fact include pit burials belonging to an unrelated *Krotovo (Locality 2) With Kurgan* mound burial ground and thus represent an artificially mixed sample.

The *Late Krotovo* sample displays significant morphogenetic divergence from all three remaining samples even when considering the larger, less variable trait list (*cf.*, Tables 4.2 and 4.3). Molodin's (1995c) suggestion that this burial ground represents the latest phase of use of Sopka-II by Krotovo populations would support this result assuming continuous microevolutionary change within the area over time. Examining the relative rank order of these MMD estimates reveals that the *Late Krotovo* crania are most divergent from the *Krotovo (Locality 2) With Kurgan* sample followed by the *Krotovo (Locality 2) Without Kurgan* and *Krotovo (Locality 1)* samples. As stated before, this limits the possibility for biological or microevolutionary relatedness between the Krotovo populations interred within kurgan burial grounds at the site. However, the closer relationship between the *Late Krotovo* sample and the similar *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* crania is more difficult to explain. The fact that the latter two groups show significant differentiation from the *Late Krotovo* population sample is clear. However, an examination of the standardized MMDs for these groups reveal near perfect triangular equality (*i.e.,* the sum of the two smallest MMD values nearly equal the one larger value), especially for the 18 trait MMD trait list. Assuming

that the MMD estimates approximate Euclidean distance, this would mean that these populations lie on a line upon which the distances between these groups are measured. Such a configuration of the standardized MMD estimates could represent a genetic continuum. However, the distances between the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* cranial samples and the *Late Krotovo* sample are fairly large and probably cannot be validly represented in Euclidean space. The simple and cautious interpretation of this relationship is that the similar cranial series from the pit burial grounds display significant morphological differentiation from the *Late Krotovo* sample. That the *Krotovo (Locality 2) Without Kurgan* cranial sample is more divergent from the *Late Krotovo* sample is likely the result of the aforementioned morphological relationship of this population with the *Krotovo (Locality 2) With Kurgan* sample which displays the greatest divergence from the *Late Krotovo* sample.

The nonmetric trait frequencies for the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* cranial samples were pooled and subsequently compared to the remaining population samples (*cf.*, Tables 4.4 and 4.5). A similar pooling of frequencies for the other population samples was not justified based upon the significant or, in the case of the *Krotovo (Locality 2) Without Kurgan* and *Krotovo (Locality 2) With Kurgan* comparison, near significant MMD estimates between these samples. The resultant standardized MMD values display significant morphogenetic divergence for all of the pooled comparisons across both the 12 trait and 18 trait analyses. In fact, the MMD estimates between the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* sample and the remaining cranial series provide the best discrimination (*i.e.,* highest standardized MMD values) of Krotovo populations at Sopka-II as determined by summing the standardized MMD values for all possible three-way sample combinations. This suggests that an interpretation of the morphogenetic relationships between the Krotovo samples at Sopka-II is best approached by considering three distinctive populations; one represented by the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan*; one represented by *Krotovo (Locality 2) With Kurgan*; and, the last represented by the *Late Krotovo*.

Previous archaeological research (Molodin 1985, 1995 a, b, c) has demonstrated that the kurgan mode of interment was introduced into the Baraba region during Krotovo times and that mortuary ritual preceding this event was characterized by simple pit

interments as observed in the *Eneolithic* , *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* burials at Sopka-II. As a result, it seems possible to assign the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* assemblages to the period directly

Table 4.4. **Mean Measure of Divergence coefficients between a pooled sample of Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan crania and the two remaining Krotovo samples using 12 nonmetric traits.**

	Pooled Dkroto/Knokurg vs. Kwkurg (Locality 2)	Pooled Dkroto/Knokurg vs. Lkroto	Kwkurg (Locality 2) vs. LKroto
Mean Measure of Divergence	0.0659	0.0470	0.0802
Standard Deviation	0.0110	0.0106	0.0163
Standardized MMD	5.9909†	4.4340†	4.9202†

Legend: † - significant at the 5 % level.

Table 4.5. **Mean Measure of Divergence coefficients between a pooled sample of Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan crania and the two remaining Krotovo samples using 18 nonmetric traits.**

	Pooled Dkroto/Knokurg vs. Kwkurg (Locality 2)	Pooled Dkroto/Knokurg vs. Lkroto	Kwkurg (Locality 2) vs. LKroto
Mean Measure of Divergence	0.0414	0.0336	0.0606
Standard Deviation	0.0092	0.0088	0.0137
Standardized MMD	4.5000†	3.8182†	4.4234†

Legend: † - significant at the 5 % level.

preceding or directly to the time of introduction of this novel mortuary ritual to the site. Given this assumption, the data from the synchronic MMD analysis suggest that at least two distinct genetic events or processes are represented in the Krotovo cranial samples from Sopka-II. It is assumed that the product of these two events are represented by the burial populations interred within the novel kurgan burial grounds (*i.e., Krotovo (Locality 2) With Kurgan* and *Late Krotovo*). The nature of these hypothesized genetic events will be examined further in the following section which presents a biological distance analysis of the above three Krotovo cranial samples in conjunction with the preceding *Eneolithic* and later *Andronovo* samples.

3.0 THE DIACHRONIC BIOLOGICAL DISTANCE ANALYSIS

The focus of analysis will now shift to the evaluation and comparison of the cranial nonmetric variation displayed between diachronic cranial samples from Sopka-II. On the basis of the above results, only three Krotovo cranial samples are considered: the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan*; the *Krotovo (Locality 2) With Kurgan*; and, the *Late Krotovo*. The *Eneolithic* crania were sampled from two burial grounds situated in the southern portion of Sopka-II (*cf.*, Maps 1 and 2). Due to the small number of Andronovo burials at the site, the *Andronovo* cranial sample includes additional skulls from the Abramovo-IV, Preobrazhenka-III and Vengerovo-I burial sites of Central Baraba. The intent of this analysis is to evaluate and clarify the biological relationships that exist between the Krotovo samples and to examine the affinity of these burial groups to previous and future inhabitants of the Central Baraba region.

It was necessary to conduct a separate trait variability analysis as a result of the new variance introduced by pooling the *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* crania and by the addition of the *Eneolithic* and *Andronovo* samples to the diachronic comparisons. The results of the univariate variance analysis are presented in Table 4.6. The intent of this analysis is to identify those nonmetric traits of most taxonomical significance for discriminating between the Eneolithic and Developed Bronze Age samples. As in the previous section, a simple chi-squared test based upon the observed, untransformed proportions was used to examine the significance of trait variability (p) between the two most divergent populations samples (*cf.*, Table 4.6). However, in several comparisons, the *Andronovo* sample represented one of the two outlying trait proportions but did not produce the most significant chi-squared value. This phenomenon is attributed directly to the small size of the *Andronovo* cranial sample. In the few cases where this occurred, the population sample with the highest chi-squared value is presented. As in the previous univariate variance analysis, the *bregmatic bone (Trait 43)* is not expressed in any of the population samples (*i.e.*, 'dummy variable') and is excluded from further consideration in the calculation of MMD values. The remaining 35 traits are sorted in increasing order by the chi-squared level of significance (p). The difference between the highest and lowest proportions for each variant across the samples

is slightly less variable than was observed between the synchronic Krotovo samples. These values range from 0% to 30%. Despite this result, the diachronic comparisons resulted in a greater number of traits that differ between the high and low samples at the 5% level of significance. In fact, 13 of the 35 traits (37%) display a significant difference in trait expression between the diachronic samples (*cf.*, Table 4.6).

Table 4.6. Results of variability analysis on 36 nonmetric traits between one Eneolithic and four Developed Bronze Age cranial samples sorted in increasing order by the chi-squared level of significance. The single and double lines indicate cut-off points at the 10% and 20% significance levels, respectively.

Nonmetric Traits	Range of Trait Frequencies								Frequency Difference	Chi-square Freq Diff	p
	Low				High						
	n	N	Freq	cranial sample	n	N	Freq	cranial sample			
25 ParFor	18	36	0.50	Andro	190	240	0.79	DKroto/Knokurg	0.29	14.343	0.000†
3 PrecondTub	22	182	0.12	DKroto/Knokurg	17	54	0.31	Kwkurg	0.19	9.992*	0.002†
37 AccInfOFor	6	42	0.14	KwkurgΔ	46	114	0.40	DKroto/Knokurg	0.26	9.384	0.002†
32 SupOrbFor	25	238	0.11	DKroto/Knokurg	27	122	0.22	Eneo	0.11	8.823	0.003†
18 TympDeh	7	124	0.06	Eneo	14	69	0.20	LKroto	0.14	8.353*	0.004†
51 CondFacDo	9	53	0.17	Kwkurg	23	55	0.42	LKroto	0.25	7.985	0.005†
12 TrochSpur	6	224	0.03	DKroto/Knokurg	12	116	0.10	Eneo	0.07	7.495*	0.006†
14 LingBri	53	100	0.53	Eneo	20	25	0.80	Andro	0.27	6.001	0.014†
11 PterSBr	6	147	0.04	DKroto/KnokurgΔ	8	55	0.15	LKroto	0.11	5.269*	0.022†
52 RockJaw	14	44	0.32	Eneo	17	30	0.57	LKroto	0.25	4.525	0.033†
45 SagSutOs	1	76	0.01	DKroto/KnokurgΔ	5	41	0.12	Eneo	0.11	4.436*	0.035†
10 PterABr	6	57	0.11	LKroto	14	50	0.28	Kwkurg	0.17	4.263*	0.039†
8 IntCondCan	14	46	0.30	LKroto	12	20	0.60	Andro	0.30	3.940*	0.047†
9 AntCondCan	9	59	0.15	LKroto	17	60	0.28	Kwkurg	0.13	2.980	0.084
39 OsLam	0	34	0.00	Kwkurg	6	48	0.13	Eneo	0.13	2.928*	0.087
2 MargFor	12	121	0.10	EneoΔ	13	65	0.20	LKroto	0.10	2.879*	0.090
42 OsAst	11	154	0.07	DKroto/Knokurg	9	56	0.16	LKroto	0.09	2.834*	0.092
44 CorSutOs	0	57	0.00	Kwkurg	5	72	0.07	Eneo	0.07	2.465*	0.116
50 FroTempArt	0	46	0.00	Kwkurg	2	19	0.11	Andro	0.11	2.090*	0.148
20 ForSpinOp	15	51	0.29	Kwkurg	24	56	0.43	LKroto	0.14	2.083	0.149
31 ZygFacFor	8	51	0.16	Kwkurg	24	92	0.26	EneoΔ	0.10	2.043	0.153
4 OsApiLig	1	28	0.04	LKroto	2	10	0.20	Andro	0.16	Fisher's Exact	0.164
21 OsJap	0	22	0.00	Andro	10	79	0.13	Eneo	0.13	1.835*	0.176
34 AccSupOFor	1	72	0.01	LKroto	5	67	0.07	Kwkurg	0.06	1.804*	0.179
41 LambSutOs	9	32	0.28	Andro	24	60	0.40	Kwkurg	0.12	1.279	0.258
5 ClinoCBri	0	22	0.00	Andro	5	50	0.10	Kwkurg	0.10	1.070*	0.301
48 OcMastSutOs	0	15	0.00	Andro	5	45	0.11	Eneo	0.11	0.655*	0.419
27 SSSTR	26	36	0.72	Kwkurg	44	54	0.81	Eneo	0.09	0.603*	0.438
13 MylohA	3	52	0.06	Kwkurg	7	60	0.12	LKroto	0.06	0.577*	0.448
46 EpiBone	4	42	0.10	LKroto	6	33	0.18	Kwkurg	0.08	0.567*	0.452
28 ParProcT	0	59	0.00	Kwkurg	2	63	0.03	LKroto	0.03	0.444*	0.505
19 ForOvInc	5	164	0.03	DKroto/Knokurg	3	48	0.06	KwkurgΔ	0.03	0.352*	0.553
24 GenPit	13	14	0.93	Andro	42	42	1.00	Eneo	0.07	0.339*	0.560
22 Metop	2	120	0.02	DKroto/Knokurg	1	38	0.03	LKroto	0.01	0.000*	1.000
40 IncaB	0	35	0.00	LKroto	1	36	0.03	Kwkurg	0.03	0.000*	1.000
43 BregBone	-	-	0.00	-	-	-	0.00	-	0.00	Dummy Variable	

Legend: * - Yate's Correction for Continuity; † - significant at the 5 % level; Δ - more significant chi-squared value than small Andro sample which possesses outer range of trait frequencies across cranial samples.

As in the previous section, two separate MMD matrices are calculated for the purpose of population comparison between the diachronic Eneolithic and Developed Bronze Age samples. The first population comparison is based upon those nonmetric

traits displaying variation up to the 10% level of significance (n = 17; *cf.*, single line cut-off in Table 4.6). The second population comparison is based upon nonmetric traits found to vary up to the 20% level of significance (n = 24; *cf.*, double line cut-off in Table 4.6). Thus, a maximum of 24 nonmetric traits are used to evaluate and compare the biological distance between the diachronic samples. This reduced trait list comprises nearly 70% of the 35 nonmetric traits considered in the univariate variance analysis and is larger than that used to compare the Krotovo samples in the synchronic analysis. All of the nonmetric variants used in the synchronic Krotovo population comparisons are maintained within the diachronic trait list with the exception of the *mylohyoid arch (Trait 13)* and *lambdoidal suture ossicle (Trait 41)*. The reduced taxonomical significance of these traits in the present comparison is directly attributable to the process of pooling the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* samples (*cf.*, Tables 4.1 and 4.6). However, an additional 8 nonmetric traits in the diachronic comparison display a difference in high and low expression below the 20% level of significance.

An examination of this list of nonmetric variants in regards to Ossenberg's (1969) classification scheme reveals a more balanced representation of the trait categories in the diachronic list than was observed for the synchronic Krotovo MMD analysis. The 'hyperostotic' variants represent just under 38% of the nonmetric traits used in the diachronic comparisons as compared to 50% in the previous synchronic analysis. This is largely the result of an increase in taxonomical significance of nonmetric traits belonging to the 'foramina, canals and grooves' trait category (n=5 traits or 21%) and the 'accessory bones of the cranial vault and sutural variations' category (n=5 traits or 21%). The remaining trait categories, 'hypostotic' and 'unclassified', are poorly represented in the reduced trait list by three and two nonmetric variants, respectively. Thus, hyperostotic variants continue to be of greatest taxonomical significance for differentiating between cranial samples at the Sopka-II site. However, the sutural and foraminal variants become increasingly significant in discriminating between the diachronic samples as opposed to the synchronic Krotovo samples.

The MMD estimates between the Eneolithic and Developed Bronze Age samples based upon 17 nonmetric traits (*i.e.*, variable at the 10% level of significance) are presented in Table 4.7. Nine out of the ten population comparisons display significance at the 5% level suggesting considerable morphogenetic diversity. However, this result is

expected since only the most discriminating traits for these samples are considered. An examination of the resultant MMD values presents several interesting results. The standardized MMD estimates between the *Eneolithic* crania and the remaining population samples all display significant morphogenetic divergence. Similarly significant estimates are observed between the younger *Andronovo* crania and the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan*, *Eneolithic*, and *Late Krotovo* population samples.

Table 4.7. **Mean Measure of Divergence coefficients between Eneolithic and Developed Bronze Age samples using 17 nonmetric traits. The upper right triangular half lists the MMD distances and corresponding standard deviations in brackets. The lower left half presents the standardized MMD values for the same comparisons. The Measure of Uniqueness for each sample is provided in the far right-hand column.**

	Eneolithic	Developed Krotovo (Locality 1) & Developed Krotovo (Locality 2) Without Kurgan (Pooled)	Developed Krotovo (Locality 2) With Kurgans	Late Krotovo	Andronovo	Measure of Uniqueness
Eneolithic	-	0.0286 (0.0070)†	0.0257 (0.0121)†	0.0350 (0.0118)†	0.0458 (0.0200)†	11.4658[3]
Developed Krotovo (Locality 1) & Developed Krotovo (Locality 2) Without Kurgan (Pooled)	4.0857†	-	0.0504 (0.0099)†	0.0344 (0.0096)†	0.0517 (0.0179)†	15.6482[1]
Developed Krotovo (Locality 2) With Kurgans	2.1240†	5.0909†	-	0.0480 (0.0148)†	0.0125 (0.0230)	11.0016[4]
Late Krotovo	2.9661†	3.5833†	3.2432†	-	0.0651 (0.0227)†	12.6604[2]
Andronovo	2.2900†	2.8883†	0.5435	2.8678†	-	8.5896[5]

Legend: † - significant at the 5 % level; [1,2...] = designates the rank order of the Measures of Uniqueness from largest to smallest.

However, a standardized MMD value of only 0.5435 was calculated for the *Andronovo* and *Krotovo (Locality 2) With Kurgan* comparison which demonstrates significant morphological similarity between these samples. As observed in the synchronic biological distance analysis, the standardized MMD estimates between the three Krotovo cranial samples continue to display significant morphogenetic divergence.

MMD values between the Eneolithic and Developed Bronze Age samples calculated upon the basis of 24 nonmetric traits (*i.e.*, variable at the 20% level of significance) are

presented in Table 4.8. The larger, more variable trait list produces only eight significant MMD estimates as opposed to nine in the 17 trait matrix. The standardized MMD value between the *Eneolithic* and *Krotovo (Locality 2) With Kurgan* samples now lies just below the significance cut-off at 1.9806. As in the synchronic biological distance analysis, the use of a larger, less variable trait list has diluted five of the resultant MMD

Table 4.8. Mean Measure of Divergence coefficients between Eneolithic and Developed Bronze Age samples using 24 nonmetric traits. The upper right triangular half lists the MMD distances and corresponding standard deviations in brackets. The lower left half presents the standardized MMD values for the same comparisons. The Measure of Uniqueness for each sample is provided in the far right-hand column.

	Eneolithic	Developed Krotovo (Locality 1) & Developed Krotovo (Locality 2) Without Kurgan (Pooled)	Developed Krotovo (Locality 2) With Kurgans	Late Krotovo	Andronovo	Measure of Uniqueness
Eneolithic	-	0.0198 (0.0059)†	0.0204 (0.0103)	0.0330 (0.0100)†	0.0460 (0.0174)†	11.2802[3]
Developed Krotovo (Locality 1) & Developed Krotovo (Locality 2) Without Kurgan (Pooled)	3.3559†	-	0.0315 (0.0085)†	0.0249 (0.0081)†	0.0477 (0.0156)†	13.1936[1]
Developed Krotovo (Locality 2) With Kurgans	1.9806	3.7059†	-	0.0371 (0.0125)†	0.0230 (0.0200)	9.8045[5]
Late Krotovo	3.3000†	3.0741†	2.9680†	-	0.0590 (0.0196)†	12.3523[2]
Andronovo	2.6437†	3.0577†	1.1500	3.0102†	-	9.8616[4]

Legend: † - significant at the 5 % level; [1, 2 ...] = designates the rank order of the Measures of Uniqueness from largest to smallest.

values resulting in the observation of fewer significant differences between the population samples. However, five out of the 10 population comparisons display higher MMD estimates as a result of the addition of seven less variable nonmetric variants to the trait list. Higher MMD values are observed in all four MMD comparisons involving the small *Andronovo* sample. The unexpected inflation of these values appears to be the result of a proportionally greater reduction in the standard deviation of these estimates in comparison to the MMD values. This is likely related to the small size of the *Andronovo* sample. The *Late Krotovo* and *Eneolithic* comparison also displays an elevated

standardized MMD estimate using the 24 trait list. The addition of seven less variable traits in this population comparison must add relevant morphological information that assists in discriminating between these cranial samples.

An examination of the pattern of variation between the first and second MMD matrices reveals that the rank order of the standardized MMD estimates between the two separate analyses has changed. This phenomenon was not observed in the synchronic Krotovo analysis. The effects of the reversals are observed in the middle range of the rank order since the two highest and three lowest standardized MMD estimates remain in the same relative position as in the 17 trait population comparison. Thus, the two highest MMD estimates still involve a comparison with the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* sample and this sample continues to display the highest Measure of Uniqueness. In addition, the two smallest MMD values still involve a comparison with the *Krotovo (Locality 2) With Kurgan* sample. The five smallest MMD values in both matrices involve comparisons with or between the *Krotovo (Locality 2) With Kurgan* and *Andronovo* samples. However, the *Krotovo (Locality 2) With Kurgan* sample now displays a lower Measure of Uniqueness than the *Andronovo* sample in the 24 trait comparison Those sample comparisons displaying a difference in rank order are found to differ from the respective values in the 17 trait matrix by magnitude alone and not in terms of the significance of the estimates. The *Eneolithic* sample still displays significant morphogenetic dissimilarity to all samples with the exception of the *Eneolithic* and *Krotovo (Locality 2) With Kurgan* comparison which now lies just under the significance cut-off (*i.e.*, standardized MMD = 2.0000). The *Andronovo* crania continue to display significant morphogenetic divergence from the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan*, *Eneolithic* and *Late Krotovo* samples and relative morphological similarity with the *Krotovo (Locality 2) With Kurgan* sample. In addition, the standardized MMD estimates between the three Krotovo samples continue to display significant morphogenetic divergence.

An interesting result of the diachronic biological distance analysis is the heightened distinctiveness of the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* crania in comparison to the remaining samples. In contrast to the previous synchronic analysis where these samples displayed the lowest overall Measures of Uniqueness, the pooled sample of these crania display the greatest distinctiveness at the diachronic level

of comparison (*cf.*, Table 4.7). In fact, the two highest MMD estimates within both matrices involve a comparison with the pooled Krotovo sample. By contrast, the *Krotovo (Locality 2) With Kurgan* and *Andronovo* crania consistently represent the least distinctive population samples as represented by their respective Measures of Uniqueness (*cf.*, Table 4.7). The low distinctiveness of the *Krotovo (Locality 2) With Kurgan* sample is at odds with the previous synchronic analysis where it represented the most distinctive cranial series among the Krotovo population samples. The decreased distinctiveness of this sample in the diachronic comparison is likely related to its relative morphological similarity to both the earlier *Eneolithic* and later *Andronovo* cranial samples. In fact, these MMD estimates represent the two lowest values within both the 17 and 24 trait matrices. Regarding the *Andronovo* cranial series, the higher standard deviation of population comparisons involving this small sample is a likely cause for the reduced distinctiveness of its standardized MMD values in comparison with the remaining populations samples.

The MMD estimates involving the *Andronovo* sample display similar rank orders across both distance matrices (*cf.*, Table 4.7 and 4.8). An examination of these MMD estimates reveals consistent morphogenetic similarity between the *Andronovo* and *Krotovo (Locality 2) With Kurgan* samples (*cf.*, Tables 4.7 and 4.8), even when considering the highly variable 17 trait list. The remaining distance coefficients across both MMD matrices display consistently significant morphological dissimilarity between the *Andronovo* crania and the remaining population samples. Assuming a significant genetic component underlying nonmetric expression, the findings would suggest the existence of biological affinity between the *Andronovo* population sample and those Krotovo (Locality 2) individuals association with kurgans. This interpretation is supported by Molodin's (1995a,c) contention that the kurgan mortuary ritual was first introduced to Sopka-II during this occupation and his attribution of the burial ground to the terminal phases of the Krotovo culture on the basis of Andronovo decorative elements within the Krotovo cultural assemblage.

It is difficult to ascertain from the data a microevolutionary process that would explain the consistent morphogenetic divergence expressed between the *Krotovo (Locality 2) With Kurgan* and the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* samples in conjunction with the consistent morphological similarity

between the *Krotovo (Locality 2) With Kurgan* and *Andronovo* samples. The MMD estimates between the three groups could suggest that no biological contact ever existed between the *Krotovo (Locality 2) With Kurgan* and pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* crania. This could be due to the chronological separation of these populations since the pooled crania are thought to represent a sample of the first Krotovo populations to occupy the Sopka-II site and no radiocarbon dates are available for the *Krotovo (Locality 2) With Kurgan* burials. However, Molodin (1995a) contends on the basis of material culture and spatial considerations that these burial grounds are contemporaneous. Several other interpretations can be forwarded if the *Krotovo (Locality 2) With Kurgan* and pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* burial grounds do in fact date to the same period. The *Krotovo (Locality 2) With Kurgan* individuals may represent an intrusive population within the region such as would result from a rapid and intensive migration (*i.e.*, gene flow) with little or no subsequent biological intermixing with local populations represented by the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* burial grounds. This hypothesis, however, is not supported by Molodin's (1995c) observation of similar grave goods within both Krotovo burial grounds and their distinctiveness in material culture and mortuary ritual from later Andronovo burials at the Sopka-II site. A third equally plausible interpretation is the occurrence of a similar rapid and intensive migration (*i.e.*, gene flow) and the subsequent occurrence of biological contact with only a small, perhaps high status, segment of the original *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* population. This hypothesis would account for the status distinction in mortuary ritual (*i.e.*, appearance of kurgan burials) between the two Krotovo populations, the asserted contemporaneity of the burial grounds and the similar typological and cultural characteristics of the artifacts within the Krotovo burials. This hypothesis also explains the weak morphological similarities observed between the *Krotovo (Locality 2) With Kurgan* and *Krotovo (Locality 2) Without Kurgan* samples in the synchronic distance analysis.

Considering the small and mixed nature of the *Andronovo* cranial sample, any interpretation of the morphological relationships between this sample and the remaining burial groups must be approached with caution. Thus, conclusive statements concerning the existence of biological affinity or divergence and the microevolutionary processes

responsible for the observed morphogenetic interrelationships must await future investigation. The morphological similarity of the *Krotovo (Locality 2) With Kurgan* and *Andronovo* samples would suggest that they are biologically related or that they share ancestral ties with early Andronovo populations advancing into the Baraba region. The unchanging significance of the standardized MMD estimates and the consistent rank order of these values across both distance matrices lends consistency to the observed morphological relationships. However, an unmentioned yet troublesome aspect of the results is the significant standardized MMD estimates calculated between the *Late Krotovo* and both the *Andronovo* and *Krotovo (Locality 2) With Kurgan* cranial samples in both the 17 and 24 trait MMD matrices. According to Molodin (1995c), the *Late Krotovo* burial ground most closely resembles the Andronovo cultural tradition on the basis of material culture attributes.

The population comparisons between the *Eneolithic* crania and the remaining Developed Bronze Age samples has produced several unexpected and largely unexplainable results. As previously stated, all of the standardized MMD estimates involving the *Eneolithic* sample display significant morphological divergence with the exception of the *Eneolithic* and *Krotovo (Locality 2) With Kurgan* comparisons which displays values that range slightly above and slightly below the significance cut-off (*i.e.*, standardized MMD = 2.0000; *cf.*, Tables 4.7 and 4.8). Thus, as stated by Sjøvold (1973), a definite conclusion concerning morphological affinity or divergence between the *Eneolithic* and *Krotovo (Locality 2) With Kurgan* samples must be reserved. Considering only the four population comparisons involving the *Eneolithic* sample, the rank order of the MMD estimates remains the same across both distance matrices (*cf.*, Table 4.7 and 4.8). The results show that the *Eneolithic* sample is most divergent from the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* crania followed by the *Late Krotovo*, *Andronovo* and *Krotovo (Locality 2) With Kurgan* samples, respectively. An explanation as to why the *Eneolithic* crania should display greater morphological similarity with the *Andronovo* and *Krotovo (Locality 2) With Kurgan* samples is not forthcoming. Considering the great span of time and culture-historical differences separating the *Eneolithic* group from the remaining Developed Bronze Age samples, one would expect the resultant distance estimates to display the largest MMD values in contrast to population comparisons between Developed Bronze Age samples. This

expectation is not supported in all population comparisons involving the *Eneolithic* crania. The comparisons between the *Eneolithic* cranial sample and both the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* and *Late Krotovo* population samples represent two of the three highest values in the 24 trait matrix and two of the five highest values in the 17 trait matrix. However, the population comparisons between the *Eneolithic* crania and the *Krotovo (Locality 2) With Kurgan* and *Andronovo* samples represent two of the three lowest MMD estimates within both distance matrices. The results do not support the expectation of the 'chronological hypothesis' since the temporally distinct *Eneolithic* crania display greater morphological similarity to the *Krotovo (Locality 2) With Kurgan* and *Andronovo* samples than does the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* crania. However, the general significance of the standardized MMD results would appear to negate the existence of ancestral relationships between the Eneolithic and both the Krotovo and Andronovo populations interred at the Sopka-II site. This interpretation supports Molodin's (1995a,b) contention that the Krotovo burial grounds at the Sopka-II site are temporally removed from the Eneolithic, and instead are attributed to the latest phases of the Krotovo culture within the Baraba region.

To further explore the observed relationships, a cluster analysis using Ward's minimum variance method (Ward 1963) was conducted on both the 17 and 24 trait standardized MMD matrices. The resultant dendrograms are presented in Figures 4.1 and 4.2. The most notable aspect of both dendrograms is the early separation of the *Krotovo (Locality 2) With Kurgan* and *Andronovo* crania from the remaining samples. The *Eneolithic*, pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan*, and *Late Krotovo* samples cluster together within a second major branch in both dendrograms. The early separation of the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan*, *Late Krotovo* and *Eneolithic* population samples along the length of this branch corroborates the significance of the standardized MMD estimates observed between these samples. A switch between the positions of the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* and *Late Krotovo* cranial series represents the only vertical change on this major branch between the two analyses. This is likely related to the aforementioned differences in rank order of standardized MMD estimates between the two distance matrices and, in particular, to the larger standardized MMD value obtained

between the *Late Krotovo* and *Eneolithic* samples when using the 24 nonmetric trait list. The effect is a slight increase in the distinctiveness of the *Late Krotovo* sample within this branch when using the larger, less variable trait list. The magnitude of the morphogenetic relationships (*i.e.*, standardized MMDs) between the population samples is represented by the horizontal length of the terminal branches. A comparison of both

Figure 4.1 **Results of a Ward minimum variance cluster analysis of standardized MMD values from the 17 trait diachronic distance matrix (*cf.*, Table 4.7). The distance metric is Euclidean Distance.**

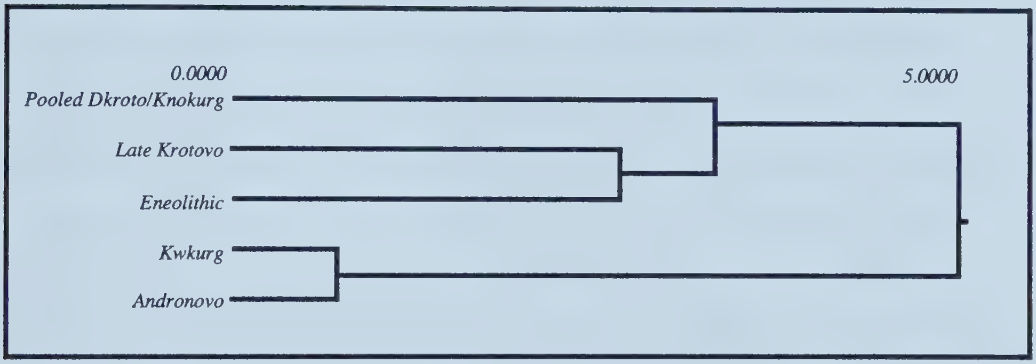
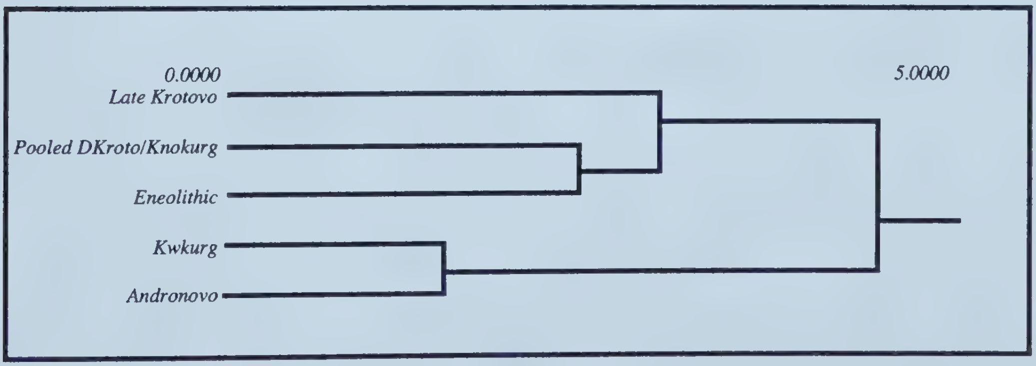


Figure 4.2 **Results of a Ward minimum variance cluster analysis of standardized MMD values from the 24 trait diachronic distance matrix (cf. Table 4.8). The distance metric is Euclidean Distance.**

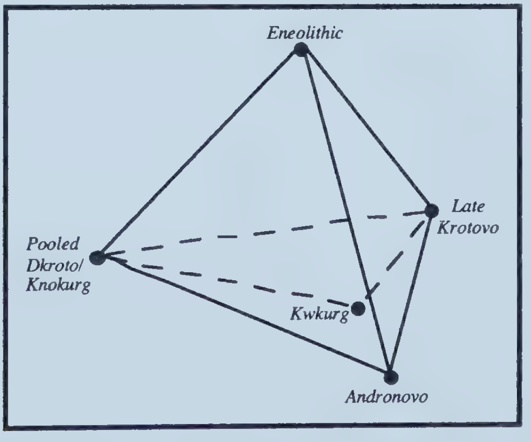


dendrograms reveals a slight decrease in the magnitude of differentiation between the two main branches when using the 24 trait standardized MMD values. Similarly, the magnitude of morphological divergence between the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan*, *Late Krotovo* and *Eneolithic* population samples in the main upper branch also decreases when using the 24 trait standardized MMDs.

However, the lower branch displays greater differentiation between the *Krotovo (Locality 2) With Kurgan* and *Andronovo* samples when using the larger, more variable trait list. As suggested before, this is likely the result of the small size of the *Andronovo* cranial series and the proportionally greater decrease in the value of the standard deviation of the distance estimates in relation to the MMD values associated with the addition of the less variable traits.

A consideration of the standardized MMD estimates and cluster dendrograms across both diachronic distance matrices reveals the existence of significant morphogenetic divergence between four out of the five burial groups. The exception to this is the *Andronovo* and *Krotovo (Locality 2) With Kurgan* population comparison. A diagram in the form of a four-pointed pyramid (*cf.*, Figure 4.3) is presented to assist in visualizing the general morphogenetic interrelationships. The lines connecting the points of the pyramid in this figure represent the standardized MMD values between population

Figure 4.3 **A relative three dimensional model of morphogenetic relationships between the five cranial samples. The distance between points represents the standardized MMD estimates.**



samples. Three of the four points are represented by the significantly divergent pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan, Late Krotovo* and *Eneolithic* samples. The remaining point includes both the *Andronovo* and *Krotovo (Locality 2) With Kurgan* samples on the basis of their shared morphogenetic affinity. This simple visual interpretation displays the major results of the synchronic and diachronic

biological distance analyses. These include:

1. the morphogenetic similarity between the *Krotovo (Locality 1)* and *Krotovo (Locality 2) Without Kurgan* cranial samples as observed in the synchronic biological distance analysis (*cf.*, pooled sample; Figure 4.3);

2. the distinctiveness of the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan*, *Krotovo (Locality 2) With Kurgan* and *Late Krotovo* samples as observed in the synchronic distance analysis (*cf.*, dotted triangle, Figure 4.3);

3. the morphogenetic dissimilarity observed between the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan*, *Krotovo (Locality 2) With Kurgan*, *Late Krotovo* and *Eneolithic* samples in the diachronic distance analysis; and,

4. the consistent morphological similarity observed between the *Krotovo (Locality 2) With Kurgan* and *Andronovo* cranial samples in the diachronic distance analysis.

CHAPTER 5: SUMMARY AND CONCLUSION

This thesis has utilized morphogenetic data obtained from cranial nonmetric traits and the 'skeletal population' model to examine the processes of biological differentiation and genetic change that occurred in human populations inhabiting the Baraba region of Western Siberia during the Eneolithic and Developed Bronze Age. This thesis represents the initial application of cranial nonmetric analysis to Eneolithic and Developed Bronze Age burial populations of the region. The analysis is small-scale both in its regional focus and in terms of the population comparisons which focus upon the biological relationships between synchronic burial populations of the Krotovo culture. Two diachronic samples representing Eneolithic and Andronovo burial groups are included in order to examine the biological relationships that exist between the Krotovo burial populations and both earlier and later populations inhabiting the area.

Despite the long-standing tradition of cranial nonmetric research and the 'skeletal population' approach in physical anthropology, the appropriateness of deriving genetic conclusions from shared patterns of qualitative morphological expression is still debated. This uncertainty has caused Molto (1983:8) to adopt the term 'morphogenetic affinity' to describe skeletal determinations of human biological relatedness and has led Saunders (1989:106) to warn that "...genetically based conclusions must be approached with caution". The relevance of cranial nonmetric data to investigations of biological processes in human populations rests upon the appropriateness of the skeletal samples and the type of nonmetric variants used in MMD population comparisons. These criteria are discussed further below.

The skeletal samples from Sopka-II have been examined in Chapter 2. The samples are determined to be of sufficient size for biological distance analysis with the exception of the small *Andronovo* cranial series (n = 19) which is below the 30 or more individuals recommended by Green and Suchey (1976) for stabilizing the variance in MMD comparisons. For this reason, MMD comparisons involving the *Andronovo* sample must be interpreted with caution. Only adult crania were selected so that developmental effects in the expression of certain nonmetric traits are minimized in the results. A noted deficiency is the limited temporal control within and between the population samples. Despite the need for additional radiocarbon dates, the small series of dates obtained for this analysis support the relative chronological scheme developed for the region

(Molodin's 1985, 1994, 1995a,b). Another noted deficiency is the limited regional focus of the population samples. The results of this analysis are formulated on the basis of Sopka-II burial populations which may not express the full range and extent of biological variability characteristic of Eneolithic and Developed Bronze Age populations of the greater Baraba region. However, the extension of the results to surrounding regions is important in a hypothetical sense and should be addressed by future research.

Chapter 3 has presented the trait list and examined both the scoring methods and distributional properties of the cranial nonmetric data. The results of a test for intraobserver scoring consistency has led to the exclusion of inconsistently scored variants from consideration in the MMD analysis. An analysis of distributional properties of the cranial nonmetric data has not identified variants that differ in expression in a biologically meaningful manner between the sides of the body or between the sexes. The absence of these types of correlations leads to the assumption that the final trait list includes only those nonmetric variants whose expression are predominantly determined by genetic factors. Subsequently, univariate variance analyses were conducted in order to identify those nonmetric traits of greatest taxonomic significance for discriminating between the cranial samples for both the synchronic and diachronic population comparisons. The final trait list selected by this method does not necessarily possess equal utility for discriminating between all of the respective samples since the test required only that the traits differ between two of the population samples at the 10% and 20% levels of significance. The resultant trait lists may be more suitable for the taxonomic classification of some populations and less suitable for others. The unexplainable patterns of cranial nonmetric expression observed for the Eneolithic crania perhaps could be attributed to this phenomenon since the univariate variance analysis in the diachronic comparison is simultaneously weighted by four Developed Bronze Age samples. In other words, the resultant trait list may be more suitable for taxonomic classification of Developed Bronze Age populations of Baraba and less suitable for identifying differences between the temporally distinct Eneolithic crania.

The significant variation displayed by 'hyperostotic' variants between the Sopka-II cranial samples has resulted in their dominant representation in the final MMD trait lists for both the synchronic (50 %) and diachronic (38 %) distance analyses. This likely reflects the larger proportion of males (61%) within the total sample of sexable skulls (n

= 297) since an association has been found between hyperostotic traits and higher male incidence (Ossenberg 1969, Molto 1983). The increased taxonomic significance of 'hyperostotic' variants among Sopka-II burial populations is troubling since the expression of many of these 'excess bone' variants is thought to be influenced as much by mechanical factors as by genes (Molto 1979). This leads to the possibility that a large proportion of the variance measured by the MMD analysis represents differences in nonmetric expression that are the result of occupational or environmental stress rather than inheritance. If true, this would greatly minimize the genetic significance of the standardized MMD estimates. Several aspects of this study decrease the possibility for significant non-genetic determination in the expression of the utilized hyperostotic traits. Firstly, those hyperostotic traits known to be associated with dietary, pathogenic, functional or mechanical influences were excluded from the initial trait list. In addition, the utilized battery of hyperostotic traits displayed the highest level of bilateral symmetry in comparison to the remaining trait categories suggesting a significant genetic component in their expression. At present, however, the limited knowledge concerning the determinance of most 'hyperostotic' variants does not allow the verification or quantification of this effect on the resultant biological distance analysis. Given knowledge about the determinance of 'hyperostotic' traits, observations of this type could contribute to future studies examining processes of human biological adaptation to external factors such as documented environmental shifts or changing subsistence strategies.

Another potentially troubling aspect of the cranial nonmetric results is the criteria by which the burial populations are formulated. By necessity, the cranial samples were distinguished on the basis of cultural uniformity in mortuary ritual and grave goods and/or spatial discreteness of the burial areas at Sopka-II. On the basis of these archaeological and spatial criteria, there is no reason to assume that these groups represent samples of biologically homogenous populations. The Russian anthropological literature abounds with references to hypothesized population migrations and the observation of varying levels of genetic admixture between 'Mongoloid' and 'Caucasoid' physical types for this period in the Baraba region (Dremov 1984; Molodin & Chikisheva 1988: 170). The geographical location of the Barabinsk forest-steppe on the boundary of the proposed 'racial' complexes and the previous observation of 'racial' heterogeneity by

Russian anthropologists increases the likelihood that each of these archaeological cultures (*i.e.*, Krotovo, Andronovo, *etc.*,) subsume populations that are different, in a biological sense, from each other. An understanding of the complex relationships that exist between cultural attributes and racial identity in the Eneolithic and Developed Bronze Age of the Baraba region is needed. Unfortunately, the common reference in the Russian literature to broadly defined 'racial' classifications are not particularly useful in determining the nature and intensity of these hypothesized population interactions and the biological heterogeneity characteristic of these human groups. The strength of the 'skeletal population' approach is its rejection of preconcieved biological classifications. The results using this model are forwarded without bias and are based solely upon morphological similarity or dissimilarity observed between skeletal samples. As a result, the nature, intensity and duration of interactions between biologically distinct populations should be represented in the standardized MMD estimates.

The use of visibly heterogeneous burial populations (*i.e.*, 'Caucasoid' and 'Mongoloid') in cranial nonmetric analysis could produce a levelling effect that would mask the detection of small scale, population processes occurring at the site since the resultant MMD estimates consider all individuals within each population sample simultaneously. Thus, morphological affinities between population samples may represent similar levels or proportions of heterogeneity within the population samples instead of true biological relatedness. Unfortunately, current methods of cranial nonmetric analysis provide no means of quantifying the levels of biological heterogeneity expressed within each separate population sample. Conclusions of this type must await the development of future methods of analysis.

A detailed examination of the Sopka-II skeletal samples and distributional aspects of the cranial nonmetric data has indicated the general appropriateness of these criteria within the present research method. Despite several recognized deficiencies, it has been determined that both are sufficient for forwarding tentative hypotheses concerning biological change as indicated by the divergent patterns of cranial nonmetric expression. Thus, the morphological information represented by the synchronic and diachronic MMD estimates is used to forward hypotheses about biological relationships between the Sopka-II burial populations. Unfortunately, supporting lines of biological evidence with which to compare the results of this analysis are limited. No cranial nonmetric research

has been conducted on burial populations of the Eneolithic and Developed Bronze Age in the vicinity of Baraba. In addition, the results of existing craniometric studies by Russian anthropologists are presented in terms of broadly defined 'racial' classifications which have proven difficult to compare and contrast with the small scale, intrapopulational analysis represented by the present study. In the absence of comparative biological data, it is difficult to confirm the relative genetic significance of cranial nonmetric expression in the Siberian samples in comparison to external, nongenetic factors. Thus, conclusions drawn from the cranial nonmetric analysis will be forwarded with caution and must be regarded as preliminary hypotheses to be tested by future biological distance research in Western Siberia.

The cranial nonmetric data do not support the existence of ancestral ties between the Developed Bronze Age burial groups (*i.e.*, Krotovo and Andronovo) and the autochthonous Eneolithic inhabitants of the region. This conclusion is tentatively supported by the great period of time separating the radiocarbon dates obtained for the Eneolithic and Developed Bronze Age burials at Sopka-II. However, the small number of radiocarbon dates presented in the study are not sufficient to conclusively resolve issues of chronology at the site. The general conclusion presented above is obscured by the less distinct morphological divergence expressed between the *Eneolithic* crania and both the *Krotovo (Locality 2) With Kurgan* and *Andronovo* cranial samples as compared to the remaining Developed Bronze Age samples. This disproves the 'chronological hypothesis' which predicts that the magnitude of morphogenetic differentiation between cranial samples should be proportional to the amount of time separating the different burial groups at the Sopka-II site. However, the possibility exists that the nonmetric traits selected for the diachronic population comparisons are not of similar taxonomic significance for comparing the Eneolithic skeletal series as compared to the Developed Bronze Age samples.

The ancestral origins of the Krotovo culture in the Baraba region are impossible to infer on the basis of the cranial nonmetric data presented in this thesis. The *Eneolithic* crania display morphological dissimilarity from all Krotovo cranial samples. A potential explanation for this situation is Molodin's (1995a,c) designation of the Krotovo burial grounds at Sopka-II to the latest phases of this culture-historical tradition. Thus, cranial samples of early Krotovo populations in the region are not represented in the current

study. Despite this, it has been argued that the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* pit interment burial grounds represent the earliest Krotovo cemeteries at Sopka-II. The separation of the four Krotovo burial grounds into three morphologically distinct groups suggest the occurrence of at least two episodes of genetic change during the Krotovo occupation of the site. The result of these biological processes are represented by the morphologically divergent *Krotovo (Locality 2) With Kurgan* and *Late Krotovo* kurgan burial grounds. The introduction of labour intensive kurgan mortuary structures during this time may suggest that the observed morphological differentiation is associated with processes of social stratification existent within the Krotovo society. The observed biological differentiation could be the result of class endogamy and resultant genetic isolation of a small, high class segment of the Krotovo population or to the appearance of an intrusive population of an elite, ruling class. The higher incidence of bilateral symmetry in cranial nonmetric expression displayed by the Krotovo kurgan groups as opposed to those samples interred in pit inhumations may reflect differences in occupation or preferential access to subsistence resources associated with these hypothesized class distinctions.

The absence of radiocarbon dates for the *Krotovo (Locality 2) With Kurgan* burial ground prevents a conclusive determination of the temporal order of this burial group relative to the *Late Krotovo* burial ground. However, previous research has demonstrated that the kurgan mode of interment was introduced into the Baraba region and that mortuary ritual preceding this event was characterized by simple pit interments. Thus, it seems reasonable to date the *Krotovo (Locality 2) With Kurgan* and *Late Krotovo* burial grounds directly to or slightly later than the time of use of the pooled *Krotovo (Locality 1) / Krotovo (Locality 2) Without Kurgan* pit interment burial grounds. On the basis of increased Andronovo cultural elements on the grave goods in the *Late Krotovo* burials, Molodin (1995a) suggests that this cemetery represents a later phase of Krotovo occupation of the site. On the basis of the present evidence, the genetic event or process identified by the *Krotovo (Locality 2) With Kurgan* cranial series may be associated with the appearance of intrusive Andronovo populations to the Baraba region and possible biological interactions with segments of the local Krotovo population. This conclusion, however, must remain hypothetical due to the small and mixed nature of the *Andronovo* cranial sample. The morphogenetic divergence of the *Late Krotovo* crania may also

represents a distinct genetic event or process that occurred during later phases of Krotovo occupation of Sopka-II. However, the significant divergence of this sample from all cranial series in both the synchronic and diachronic distance analyses does not permit an explanation of the nature or origin of this process.

The results of the present study should be viewed as an initial attempt at understanding the biological relationships and microevolutionary processes (*i.e.,* the direction of gene flow and the amount of genetic drift and admixture) characteristic of populations inhabiting the Baraba region over the Eneolithic and Developed Bronze Age. The accumulated data contribute a biological context to local culture-historical reconstructions that is important for determining whether the changing material culture and subsistence strategies observed in the archaeological record are related to population migrations into and out of the region. Of additional interest to archaeologists is the higher level of bilateral symmetry in nonmetric trait expression observed among the *Krotovo (Locality 2) With Kurgan*, *Late Krotovo* and *Andronovo* burial populations. The differential ability of kurgan versus non-kurgan burial populations at Sopka-II to develop symmetrically could be related to a multitude of factors including nutrition, the relative success of different economic strategies, status and differential access to resources, or divisions of labor with corresponding differences of biomechanical stress. The information obtained from this research, in conjunction with other skeletal metric and nonmetric studies and evidence from the disciplines of archaeology, linguistics and molecular biology (*i.e.,* ancient DNA), can be used by future investigators to construct models of genetic variability for the entire Western Siberian region during the Holocene.

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APPENDICES

APPENDIX A: CRANIAL NONMETRIC TRAIT DESCRIPTIONS

Hyperostotic Traits

1. **Auditory torus (AudTorus; r^2= 0.032):** A bony ridge or torus of variable size may protrude from the floor of the external auditory meatus. This trait was scored following Buikstra's (1976:84) method: (0) absent, (1) less than one-third of the auditory aperture occluded (*i.e.,* includes trace appearance of irregular bony growth), (2) between one-third and two-thirds occluded, and (3) more than two thirds occluded (illustrated in Hauser and De Stefano 1989:181). In determining sample frequencies for this trait, any positive expression (*i.e.,* 1, 2 or 3) was regarded as present.

2. **Marginal foramen (MargFor; r^2= 0.695):** The groove that houses the auriculo-temporal nerve extends in a medio-lateral direction along the inferior margin of the tympanic plate towards the often times porous lateral margin. A pair of bony spicules growing from the sides of this groove along its lateral margin may join to form a canal or foramen of variable length. This trait was scored following Molto's (1983:119) method: (0) absent and (1) any canal formed by the union of bony spicules over the auriculo-temporal groove (illustrated in Molto 1983:285; Hauser and De Stefano 1989:27).

3. **Precondylar tubercle (PrecondTub; r^2= 0.667):** One or a pair of bony tubercles of variable size may be present on the smooth anterior margin of the foramen magnum, immediately anteromedial to the occipital condyles. The precondylar tubercle is distinguished from the ossified apical ligament (Trait 4) by its anterior placement away from the interior margin of the foramen magnum and by the generally inferior direction of the projection. This trait was scored following Berry and Berry's (1967) method: (0) absent and (1) presence of one or two precondylar tubercles (illustrated in Berry and Berry 1967:366; Hauser and De Stefano 1989:113,119,136).

4. **Ossified apical ligament (OsApiLig; r^2= 0.682):** The apical ligament extends from the superior portion of the odontoid process of the axis vertebrae to a point on the midline in the anterior and interior margin of the foramen magnum. This ligament may ossify creating a bony tubercle of variable size that extends posteriorly into the foramen magnum. As compared to the precondylar tubercle (Trait 3), the ossified apical ligament is located directly on the interior margin of the foramen magnum and projects more towards the posterior than inferior. This trait was scored following Molto's (1983:121-122) method: (0) absent and (1) presence of any bony projection in the midline of the anterior and interior margin of the foramen magnum (illustrated in Molto 1983:287).

5. **Clino-clinoid bridge (ClinoCBri; r^2= 0.741):** The ossification of the ligaments joining the anterior and posterior clinoid processes on either side of the sellae turcica may result in the formation of a complete bony bridge or unfused spicules of varying length. This trait was scored following Molto's (1983:122-123) method: (0) absent, (1) the presence of contact spurs with flattened bony ends giving the appearance of a joint, and (2) the presence of a complete bony bridge (illustrated in Molto 1983:288; Hauser and De Stefano 1989:159). In determining sample frequencies for this trait, any positive expression (*i.e.,* 1 or 2) was regarded as present.

6. **Carotico-clinoid bridge (CarotCBrid; r^2= 0.486):** The ossification of the ligaments joining the anterior and middle clinoid processes on either side of the sellae turcica may result in the formation of a complete bony bridge or unfused spicules of varying length. This trait was scored following Molto's (1983:122-123) method: (0) absent, (1) the

presence of contact spurs with flattened bony ends giving the appearance of a joint, and (2) the presence of a complete bony bridge (illustrated in Molto 1983:288; Hauser and De Stefano 1989:159). In determining sample frequencies for this trait, any positive expression (*i.e.,* 1 or 2) was regarded as present.

7. Paracondylar process (PCondPro; r^2= 0.394): A bony process may occur in the area between the occipital condyle and the mastoid process, just posterior to the jugular fossa. This trait was scored following Hauser and De Stefano's (1989:129) method: (0) absent, (1) protruding less than 1 mm from the base of the skull, (2) protruding between 1 and 3 mm, and (3) protruding greater than 3 mm (illustrated in Hauser and De Stefano 1989:113,130). Sample frequencies for this trait were determined by including only the medium and strong expressions (*i.e.,* 2 and 3) because of difficulties in delineating between weak expressions (*i.e.,* 1) and normal irregularities commonly observed in this basal region of the skull.

8. Intermediate condylar canal (IntCondCan; r^2= 0.776): A groove that houses small emissary veins often runs in a posterolateral direction immediately lateral to the occipital condyles (Ossenberg 1976). If the anterior portion of this groove between the occipital condyles and the jugular fossa is deep, the lateral margin sometimes expresses a sharp crest. The groove may convert to a canal of variable length when the lateral lip extends medially and fuses to the side of the condylar process. This trait was scored following Molto's (1983:122) method: (0) absent and (1) presence of a completely formed canal (illustrated in Molto 1983:287; Hauser and De Stefano 1989:113,127).

9. Anterior condylar canal double (AntCondCan; r^2= 1.000): The anterior condylar canal (hypoglossal canal) passes through the anterior portion of the base of the occipital condyles in a mediolateral direction, transmitting the hypoglossal nerve. Due to variations in the course of the nerve, the canal may be divided by one or more complete, or incomplete, bony bridges at its medial or interior portions or, more rarely, along its entire length. This trait was scored following Buikstra's (1976:84) method: (0) absent, (1) incomplete bridging on medial surface of the canal, (2) complete bridging on medial surface of the canal, (3) incomplete bridging in internal portions of canal, and (4) complete bridging on internal portions of canal (illustrated in Berry and Berry 1967:364; Hauser and De Stefano 1989:123). In determining sample frequencies for this trait, any positive expression (*i.e.,* 1, 2, 3 or 4) was regarded as present.

10. Pterygo-alar bridge (partial) (PterABr; r^2= 0.718): Variable ossification of the pterygo-alar (basal) ligament may result in the formation of a complete, or incomplete, bony bridge that connects the inferolateral surface of the greater wing of the sphenoid with the root of the lateral pterygoid plate. This bridge transforms a groove that is frequently present in the greater wing into a canal and is located directly anterolateral to foramen ovale. This trait was scored following Hauser and De Stefano's (1989:157) method: (0) absent, (1) presence of small spines or tubercles (on both sides), (2) presence of incomplete bridging (elongated spines on both sides), and (3) complete bridging (including bridges with small fissures) (illustrated in Molto 1983:287; Hauser and De Stefano 1989:158-159). In determining sample frequencies for this trait, any positive expression (*i.e.* 1, 2 or 3) was regarded as present.

11. Pterygo-spinous bridge (partial) (PterSBr; r^2= 0.652): The spina angularis is located on the inferior surface of the greater wing of the sphenoid and is the osseous structure within which the foramen spinosum is located. Variable ossification of a ligament that connects the downward projecting tip of the spina angularis, lateral to the

foramen spinosum, with the lateral pterygoid plate may result in the formation of a complete, or incomplete, bony bridge. This trait was scored following Hauser and De Stefano's (1989:157) method: (0) absent, (1) presence of small spines or tubercles (on both sides), (2) presence of incomplete bridging (elongated spines on both sides), and (3) complete bridging (including bridges with small fissures) (illustrated in Molto 1983:287; Hauser and De Stefano 1989:158-159). In determining sample frequencies for this trait, only partial and complete bridges (*i.e.* 2 or 3) were regarded as present. The reason for the scoring discrepancy between this and the former trait is that a higher incidence of partial and complete pterygo-spinous bridging (*i.e.*, 2 and 3) was observed.

12. Trochlear spur (TrochSpur; r^2= 1.000): An osseous spine of various length and size may project from just below the superomedial angle of the orbital rim in the region where the trochlear pit (foveola) is normally expressed. This trait was scored following Hauser and De Stefano's (1989:65) method: (0) absent, (1) trace spur that is barely visible but palpable, (2) moderate and easily visible spur development up to 2 mm in length, and (3) strong spur development greater than 2 mm in length (illustrated in Hauser and De Stefano 1989:61; Molto 1983:284). In determining sample frequencies for this trait, any positive expression (*i.e.*, 1, 2 or 3) was regarded as present.

13. Mylohyoid arch (MylohA; r^2= 0.791): The mandibular foramen is located on the medial surface of the mandibular ramus. From this foramen, a mylohyoid groove of variable depth leads in an anteroinferior direction. The margins of this groove may display sharp projections that form a complete, or incomplete, roof that transform the structure into a canal of various lengths. This trait was scored following Hauser and De Stefano's (1989:234-235) method: (0) absent, (1) partial arch that displays clearly developed spicule formation, (2) completed arch of limited development along the mylohyoid groove, and (3) complete arch along the entire extent of the groove (illustrated in Hauser and De Stefano 1989:231,235). In determining sample frequencies for this trait, only complete arching (*i.e.*, 2 or 3) was regarded as present.

14. Lingula bridge (LingBri; r^2= 0.696): The lingula is a sharp, variably shaped osseous projection at the anterior edge of the mandibular foramen. The lingula is commonly blunt but may extend posteriorly to form a sharp projection or a complete bridge across the foraminal opening. The trait was scored following Lovell's (1994) method: (0) absent, (1) lingula spur or hook extending into the foraminal opening (including trace sharp extensions of the lingula), and (2) complete bridging of the foraminal opening (no illustration). In determining sample frequencies for this trait, any positive expression (*i.e.*, 1 or 2) was regarded as present.

15. Genial tubercles (GenTub; r^2= 0.477): On the lingual surface of the mandible, on or around the midline of the body, is commonly expressed up to four genial tubercles in various numbers and combinations. This trait was scored following Lovell's (1994) method: (0) absent and (1) present (indicating the number of tubercles present) (illustrated in Hauser and De Stefano 1989:231,239).

16. Median mental spine (MMentSp; r^2= 0.561): A single median spine of variable size and shape may occur on or around the midline of the body on the interior surface of the mandible, usually expressed in place of genial tubercles. This trait was scored as (0) absent and (1) presence of a spine on the midline that displays significant length in the inferosuperior dimension (illustrated in Hauser and De Stefano 1989:231,239).

Hypostotic Traits

17. Biasterionic suture (BiAstSut; r^2= 0.365): The biasterionic or mendosal suture may occur on the lateral margins of the occipital squama, originating from the vicinity of asterion and extending medially approximately along the course of the highest nuchal line. Molto (1983:118) cautions researchers of possible confusion between the presence of a biasterionic suture in this vicinity and the unfused inferior remnants of a large lambdoidal suture ossicle. The maximum length of this suture is 30 mm and it never completely bisects the occipital squama as does the transverse occipital suture. This trait was scored as follows: (0) absent and (1) presence of suture greater than 1 cm and less than 3 cm in length (illustrated in Hauser and De Stefano 1989:195; Molto 1983:285-286).

18. Tympanic dehiscence (TympDeh; r^2= 0.824): The tympanic plate forms the inferior portion of the external auditory canal. In rare instances, this plate may be completely absent, but more commonly it may display a perforation of variable size and shape within the medial one-third. This trait was scored following Dodo's (1974) method: (0) absent, (1) trace translucence of tympanic plate observed with the aid of light source, (2) presence of a perforation of the tympanic plate of variable size, (3) partial absence of the plate, and (4) complete absence of the tympanic plate (illustrated in Hauser and De Stefano 1989:145; Molto 1983:285). In determining sample frequencies for this trait, any positive expression of perforation of the tympanic plate (*i.e.*, 2, 3 or 4) was regarded as present.

19. Foramen ovale incomplete (ForOvInc; r^2= 0.791): The foramen ovale is situated on the sphenoid bone directly posterior to the foramen rotundum. The posterolateral portion of this foramen is sometimes absent, creating a continuous confluence with the foramen spinosum. This trait was scored following Berry and Berry's (1967) method: (0) foramen ovale complete and (1) incomplete formation with associated communication with the foramen spinosum (illustrated in Berry and Berry 1967:366; Hauser and De Stefano 1989:150,152).

20. Foramen spinosum open (ForSpinOp; r^2= 0.798): The posteromedial wall of the foramen spinosum may sometimes be deficient or open to varying degrees, resulting in a confluence of this foramen with the spheno-petrous fissure. This trait was scored following Berry and Berry's (1967) method: (0) foramen closed and (1) foramen open (illustrated in Berry and Berry 1967:366; Hauser and De Stefano 1989:150,152).

21. Os japonicum (trace) (OsJap; r^2= 0.756): The division of the zygomatic bone by one or two transverse sutures is called Os japonicum. This trait is scored following Ossenberg's (1976) method: (0) normal zygomatic bone (1) trace presence of suture regardless of length and (2) complete division of zygomatic bone (illustrated in Hauser and De Stefano 1989:210,224 and Molto 1983:285). In determining sample frequencies for this trait, any positive expression (*i.e.*, 1 or 2) was regarded as present.

22. Metopism (Metop; r^2= 1.000): At birth, the medio-frontal suture divides the frontal bone into two separate halves from bregma to nasion. When this suture persists, in part or in total, beyond the time of its normal obliteration it is called the metopic suture. This trait is scored following Buikstra and Ubelaker's (1994:87) method: (0) absent, (1) partial persistence of the suture, and (2) complete metopic suture (illustrated in Buikstra and Ubelaker 1994:87; Hauser and De Stefano 1989:45). In determining sample frequencies for this trait, any positive expression (*i.e.*, 1 or 2) was regarded as present.

23. Infraorbital suture (trace) (InfOSut; r^2= 0.209): The infraorbital suture follows the superficial course of the infraorbital canal from the orbital floor along the facial surface of the maxilla. This suture may terminate before reaching the facial part of the maxilla or may extend partially or completely to the infraorbital foramen. This trait was scored following Ossenberg's (1969) method: (0) absent on facial part of maxilla, (1) trace presence of the suture on the facial part of maxilla not extending to the infraorbital foramen, and (2) complete presence of the suture from infraorbital rim to infraorbital foramen (illustrated in Hauser and De Stefano 1989:61,68; Molto 1983,284). In determining sample frequencies for this trait, both trace and complete expressions (*i.e.*, 1 or 2) were regarded as present.

24. Genial pits (GenPit; r^2= 1.000): On the lingual surface of the mandible, on or around the midline of the body, may be expressed one or two pits, a pit in combination with a tubercle or the complete absence of pits. This trait was scored following Lovell's (1994) method: (0) absent and (1) present (indicating the number of pits present) (illustrated in Hauser and De Stefano (1989:239)).

Foramina, Canals and Grooves

25. Parietal foramina (ParFor; r^2= 0.873): Two bilateral foramina may pierce the parietal bone directly on either side of the sagittal suture between four and seven centimeters anterior to lambda. This trait was scored following Berry and Berry's (1967) method: (0) absent and (1) presence of parietal foramen that communicates with the endocranium (illustrated in Berry and Berry 1967:365; Hauser and De Stefano 1989:79; Molto 1983:286).

26. Obelionic foramen (ObelFor; r^2= 0.625): A foramen may be located at obelion which is found at the intersection on the sagittal suture of a line drawn between the two parietal foramina. This trait was scored as follows: (0) absent and (1) presence of a foramen at obelion that communicates with the endocranium (no illustration).

27. Superior sagittal sulcus turns right (SSSTR; r^2= 0.765): The superior sagittal sinus (superior longitudinal sinus) flows longitudinally along the endocranial midline of the occipital bone within the superior sagittal sulcus. This sulcus usually turns to the right, but may turn to the left, in the vicinity of the internal occipital protuberance. This trait was scored following Buikstra's (1976: 85) method: (0) superior sagittal sulcus turns left and (1) superior sagittal sulcus turns right.

28. Parietal process of temporal (ParProcT; r^2= 1.000): A thin projection of the superior margin of the temporal squama may protrude to various widths and lengths overtop of the parietal bone. It is distinguished from other projections of the oftentimes jagged temporal margin by the presence of branching grooves on the parietal bone superior to it. This trait was scored following Molto's (1983:126-127) method: (0) absent and (1) presence of a parietal process of the temporal bone (illustrated in Molto 1983:285).

29. Posterior condylar canal patent (PCondCan; r^2= 0.593): The exterior orifice of the posterior condylar canal may or may not be present within the condylar fossa located directly posterior to both occipital condyles. These canals run in a posteroanterior direction and, even when present, may end blindly without penetrating the endocranium. This trait was scored following Berry and Berry's (1967) method: (0) absent or presence

of non-patent condylar canal and (1) presence of patent condylar canal (illustrated in Berry and Berry 1967:366; Hauser and De Stefano 1989:105; Molto 1983:287). Particular care must be taken when scoring poorly preserved skulls for this trait since it is nearly impossible to distinguish between a broken condylar fossa and a patent canal (Berry and Berry 1967).

30. Accessory lesser palatine foramen (AccLPalFo; r^2= 0.552): The greater palatine foramen is located in the posterolateral region of the hard palate along the suture dividing the alveolar process of the maxilla from the horizontal plate of the palatine bone. Immediately posterior to the greater palatine foramina may be found one or more lesser palatine foramen. This trait was scored following Berry and Berry's (1967) method: (0) absence or presence of a single lesser palatine foramen and (1) presence of accessory lesser palatine foramina (illustrated in Berry and Berry 1967:366; Hauser and De Stefano 1989:169,175).

31. Zygomaticofacial foramen double (ZygFacFor; r^2= 0.756): One or more zygomaticofacial foramina of various size(s) may occur on the facial portion of the zygomatic bone in the region below the inferolateral angle of the orbit and superior to the zygomaxillary tubercle. In rare instances, the foramen may be absent. This trait was scored as (0) absent, (1) one large foramen or one large plus one smaller, (2) multiple small foramina (3) two large foramina or two large plus one smaller and (4) multiple large foramina (illustrated in Hauser and De Stefano 1989:211,228; Molto 1983:285). In determining sample frequencies for this trait, only the expression of two or more large foramina (*i.e.*, 3 or 4) was regarded as present.

32. Supraorbital foramen (complete) (SupOrbFor; r^2= 0.773): The supraorbital foramen or notch is usually found within the medial half of the supraorbital margin. In rare instances, the nerves and vessels that create the foramen shift their course or bifurcate before reaching the orbital margin resulting in either more lateral placement of the supraorbital foramen or the existence of several foramina or notches. To avoid confusion, this trait refers only to the most medially-expressed supraorbital foramen and is never scored if lying beyond the mid-line of the supraorbital rim. This trait was scored following Buikstra's (1976:84) method: (0) absent or slight notch present without spicules, (1) presence of an incomplete foramen that includes distinct spicule formation on one or both sides of the notch and (2) the presence of a complete supraorbital foramen (illustrated in Hauser and De Stefano 1989:52; Molto 1983:284). In determining sample frequencies for this trait, only the expression of a complete foramen (*i.e.*, 2) was regarded as present.

33. Frontal foramen or notch (FroFor; r^2= 0.504): A distinct secondary foramen or notch may appear near to the orbital margin alongside, and usually lateral to, the supraorbital foramen. The scoring of this trait did not include the presence of tiny foramen in the vicinity and sometimes lying within the supraorbital foramen. In addition, this trait includes only those secondary foramina that are situated directly along the supraorbital rim. Buikstra's (1976:84) method for scoring supraorbital foramina was applied to this trait: (0) absent or slight notch present without spicules, (1) presence of an incomplete foramen that includes distinct spicule formation on one or both sides of the notch and (2) the presence of a complete frontal foramen (illustrated in Berry and Berry 1967:365,367; Hauser and De Stefano 1989:52). In determining sample frequencies for this trait, the expression of a distinct notch, with spicules, or a complete foramen (*i.e.*, 1 or 2) was regarded as present.

34. Accessory supraorbital foramina (AccSupOFor; r^2= 1.000): Additional accessory foramina may penetrate the frontal bone directly along or at some distance superior to the supraorbital rim and generally lateral to the supraorbital foramen and frontal foramen or notch. The scoring of this trait did not include expressions of the supraorbital or frontal foramen/notch as described above and, as such, these traits were positively scored in nearly all cases where accessory supraorbital foramina were present. A source of scoring difficulty was the presence of an accessory foramen some distance above the supraorbital rim in the absence of a frontal foramen or notch directly along the supraorbital border. In all cases, these foramina were scored as accessory supraorbital foramina and not as frontal foramen or notch present. This trait was scored as (0) absent and (1) presence of accessory supraorbital foramina (no illustration).

35. Frontal grooves (FroGroove; r^2= 0.607): Distinct grooves of variable number, length, depth and course may occur on the squamous portions of the frontal bone extending obliquely from the median frontal boss or eminence towards the temporal line. In rare instances, these grooves may be covered by bony bridges making them difficult to observe. This trait was scored following Ossenberg's (1969) method: (0) absent and (1) presence of distinct grooves on frontal bone (illustrated in Hauser and De Stefano 1989:49; Molto 1983:284).

36. Supratrochlear notch or canal (SupTNot; r^2= 0.630): A small notch or canal that transmits the supratrochlear nerve may be present in the superomedial angle of the orbital rim and medial to the supraorbital foramen. This trait was scored (0) absent, (1) presence of a distinct notch, and (2) presence of a complete supratrochlear canal (illustrated in Hauser and De Stefano 1989:54). In determining sample frequencies for this trait, any positive expression of a notch or canal (*i.e.*, 1 or 2) was regarded as present.

37. Accessory infraorbital foramen (AccInfOFor; r^2= 0.679): The infraorbital foramen represents the external termination of the infraorbital canal and is located between the infraorbital rim and the canine fossa on the anterior portion of the maxilla. An accessory foramen or foramina of variable location and size may occur in association with the infraorbital foramen. This trait was scored as follows: (0) absence of accessory foramen or partial/complete internal division of a single infraorbital foramen, (1) presence of a distinct accessory infraorbital foramen, and (2) presence of several distinct accessory foramina (illustrated in Berry and Berry 1967:365,367; Hauser and De Stefano 1989:71,73). In determining sample frequencies for this trait, any positive expression of one or more distinct accessory foramina (*i.e.*, 1 or 2) was regarded as present.

38. Accessory mental foramen (AccMentFor; r^2= 0.440): The mental foramina are located on either side of the external surface of the mandible just inferior to the premolar region. An accessory foramen or foramina of variable size and location may occur in association with the mental foramen. This trait was scored following Corruccini's (1974) method: (0) absent and (1) presence of an accessory foramen or foramina (illustrated in Hauser and De Stefano 1989:231).

Accessory Bones of the Cranial Vault and Sutural Variations

39. Ossicle at lambda (OsLam; r^2= 1.000): An accessory ossicle may occur at the junction of the sagittal and lambdoid sutures at the ectocranial point known as lambda. No size limitation was imposed as long as the ossicle was clearly defined. This trait is distinct from the Inca bone (Trait 40) and was scored following Berry and Berry's (1967)

method: (0) absent and (1) presence of an ossicle at lambda (illustrated in Berry and Berry 1967:364,365; Hauser and De Stefano 1989:98).

40. Inca bone (IncaB; r^2= 1.000): The inca bone is located in the superior-most, membranous portion of the occipital squama between the two parietal bones and is separated from the inferior portions of the occipital bone by the transverse occipital suture. It is distinguished from an ossicle at lambda (Trait 39) by the position of the transverse occipital suture which lies along the highest nuchal line. The transverse occipital suture may be incompletely expressed, creating what is known as a partial inca bone. This condition is distinguished from a biasterionic suture if the suture extends greater than 3 cm from the vicinity of asterion. The Inca bone may be further subdivided by additional longitudinal or transverse sutures creating bipartite, tripartite or multipartite inca bones. This trait was scored as follows: (0) absent, (1) presence of single inca bone (symmetrical or asymmetrical), (2) presence of bipartite inca bone, (3) presence of tripartite inca bone, and (4) presence of partial inca bone with persisting transverse occipital suture greater than 30 mm in length (illustrated in Hauser and De Stefano 1989:100-101). In determining sample frequencies for this trait, any positive expression (*i.e.*, 1, 2, 3 or 4) was regarded as present.

41. Lamdoidal suture ossicle (LambSutOs; r^2= 0.881): Accessory sutural bones of various size, position and number may occur along the lambdoid suture that joins both of the parietal bones with the occipital squama. No size limitation was imposed as long as the sutural bone was clearly defined. The scoring of this trait did not include the presence of ossicles at lambda or asterion. This trait was scored following Berry and Berry's (1967) method: (0) absent and (1) presence of lambdoidal suture ossicles (illustrated in Berry and Berry 1967:364).

42. Ossicle at asterion (OsAst; r^2= 0.713): An accessory ossicle may occur at the junction of the posteroinferior angle of the parietal bone with the occipital bone and the mastoid portion of the temporal bone at the ectocranial point known as asterion. No size limitation was imposed as long as the ossicle was clearly defined. This trait was scored following Berry and Berry's (1967) method: (0) absent and (1) presence of an ossicle at asterion (illustrated in Berry and Berry 1967:365).

43. Bregmatic bone (BregBone; r^2= 1.000): An accessory ossicle may occur at the junction of the sagittal and coronal sutures at the ectocranial point known as bregma. No size limitation was imposed as long as the ossicle was clearly defined. This trait was scored following Berry and Berry's (1967) method: (0) absent and (1) presence of an ossicle at bregma (illustrated in Berry and Berry 1967:365; Hauser and De Stefano 1989:98).

44. Coronal suture ossicle (CorSutOs; r^2= 0.658): Accessory sutural bones of various size, position and number may occur along the coronal suture that joins both of the parietal bones with the squamous portions of the frontal bone. No size limitation was imposed as long as the sutural bone was clearly defined. The scoring of this trait did not include the presence of an ossicle at bregma. This trait was scored following Berry and Berry's (1967) method: (0) absent and (1) presence of coronal suture ossicles (illustrated in Berry and Berry 1967:367; Hauser and De Stefano 1989:98).

45. Sagittal suture ossicle (SagSutOs; r^2= 1.000): Accessory sutural bones of various size, position and number may occur along the sagittal suture that joins both of the parietal bones along the midline of the skull. No size limitation was imposed as long as

the sutural bone was clearly defined. The scoring of this trait did not include the presence of an ossicle at bregma or lambda. Although not scored by Berry and Berry (1967), their method for scoring sutural ossicles was applied as follows: (0) absent and (1) presence of sagittal suture ossicles (no illustration).

46. Epipteric bone (EpiBone; r^2= 0.887): An accessory ossicle (epipteric or pterionic bone) may occur between the anterior inferior angle of the parietal bone and the greater wing of the sphenoid. In rare instances, this ossicle may also articulate with the squamous portion of the temporal bone. No size limitation was imposed as long as the ossicle was clearly defined. This trait was scored following Berry and Berry's (1967) method: (0) absent and (1) presence of an epipteric bone (illustrated in Berry and Berry 1967:365; Hauser and De Stefano 1989:211,212).

47. Parietal notch bone (ParNotBone; r^2= 0.577): The parietal bone often extends in an inferoanterior direction between the squamous and mastoid portions of the temporal bone creating what is known as the parietal notch. One or more accessory ossicles may occur within this notch. No size limitation was imposed as long as the ossicle was clearly defined. This trait was scored following Berry and Berry's (1967) method: (0) absent and (1) presence of a parietal notch bone (illustrated in Berry and Berry 1967:365).

48. Occipitomastoid suture ossicle (OcMastSutOs; r^2= 0.658): Accessory sutural bones of various size, position and number may occur along the occipitomastoid suture that joins the squamous portion of the occipital bone with the mastoid portion of the temporal bone. No size limitation was imposed as long as the sutural bone was clearly defined. The scoring of this trait did not include the presence of an ossicle at asterion. Although not scored by Berry and Berry (1967), their method for scoring sutural ossicles was applied as follows: (0) absent and (1) presence of occipitomastoid suture ossicles (illustrated in Hauser and De Stefano 1989:195).

49. Nasal bone variation (NasBone; r^2= 0.638): Variations may occur in the course of the suture that joins the nasal bones along the midline of the skull. This trait is scored as follows: (0) normal straight suture following the midline of the skull and (1) the presence of sutural variations as shown in Brothwell (1981:46).

50. Fronto-temporal articulation (FroTempArt; not observed): The frontal bone is usually separated from the squamous portion of the temporal bone by the greater wing of the sphenoid and the anteroinferior angle of the parietal bone. In rare instances, the frontal and temporal bone may come into contact to varying degrees. This trait was scored following Berry and Berry's (1967) method: (0) normal separation of the frontal and temporal bones and (1) articulation of the frontal and temporal bones of any kind (illustrated in Berry and Berry 1967:367; Hauser and De Stefano 1989:217).

Unclassified Traits

51. Condylar facet double (partial) (CondFacDo; r^2= 0.715): The occipital condyles are situated directly alongside and anterolateral to the foramen magnum. The articular surface of the occipital condyles may be smooth or divided partially or completely into anteromedial and posterolateral halves. This trait was scored following Hauser and De Stefano's (1989:118) method: (0) normal smooth articular facet, (1) partial division of the articular surface including those facets displaying distinct pinching and angular changes at the midline along the long axis, and (2) complete separation of the articular surface

(illustrated in Berry and Berry 1967:366; Hauser and De Stefano 1989:113,119). In determining sample frequencies for this trait, any positive expression of facet division (*i.e.*, 1 or 2) was regarded as present.

52. Rocker jaw (RockJaw; r^2= 1.000): The inferior surface of the horizontal ramus of the mandible can display pronounced convexity such that the specimen may rock back and forth when placed on a flat surface. This trait was scored following Lovell's (1994) method: (0) absent (mandible will not rock back and forth on a flat surface), (1) almost rocker (mandible will rock for approximately 1 second), and (2) rocker (mandible will rock for several seconds) (no illustration). In determining sample frequencies for this trait, any positive expression of rocker jaw (*i.e.*, 1 or 2) was regarded as present.

APPENDIX B - NONMETRIC TRAIT FREQUENCIES OF SIBERIAN CRANIAL SAMPLES BY THE 'CRANIAL' AND 'SIDE' METHODS

Eneolithic

Traits	Trait Abbreviations	Cranial method			Crania	Side method			Sides/Crania
		n	N	Incidence	Unobservable	n	N	Incidence	Unobservable
1 Auditory Torus √	AudTorus	18	64	0.28	1	23	120	0.19	10
2 Marginal foramen/canal √	MargFor	10	68	0.15	1	12	121	0.10	17
3 Precondylar tubercle √	PrecondTub	13	52	0.25	17	19	99	0.19	39
4 Ossified apical ligament	OsApiLig	6	48	0.13	21	6	48	0.13	21
5 Clino-clinoid bridge √	ClinoCBri	3	36	0.08	33	5	60	0.08	78
6 Carotico-clinoid bridge √	CarotCBri	4	33	0.12	36	7	54	0.13	84
7 Paracondylar process √	PCondPro	16	26	0.62	43	23	43	0.53	95
8 Intermediate condylar canal √	IntCondCan	22	44	0.50	25	32	75	0.43	63
9 Anterior condylar canal double √	AntCondCan	15	52	0.29	17	20	98	0.20	40
10 Pterygo-alar bridge (partial) √	PterABr	15	58	0.26	11	18	98	0.18	40
11 Pterygo-spinous bridge (partial) √	PterSBr	5	55	0.09	14	6	93	0.06	45
12 Trochlear spur √	TrochSpur	9	61	0.15	8	12	116	0.10	22
13 Mylohyoid arch √	MylohA	4	54	0.07	15	6	97	0.06	41
14 Lingula bridge √	LingBri	32	54	0.59	15	53	100	0.53	38
15 Genial tubercles	GenTub	43	44	0.98	25	43	44	0.98	25
16 Median mental spine	MMentSp	14	44	0.32	25	14	44	0.32	25
17 Biasterionic suture √	BiAstSut	11	52	0.21	13	15	95	0.16	35
18 Tympanic dehiscence √	TympDeh	6	68	0.09	1	7	124	0.06	14
19 Foramen ovale incomplete √	ForOvInc	5	58	0.09	11	6	97	0.06	41
20 Foramen spinosum open √	ForSpinOp	24	55	0.44	14	28	92	0.30	46
21 Os japonicum (trace) √	OsJap	7	51	0.14	18	10	79	0.13	59
22 Metopism	Metop	1	53	0.02	12	1	53	0.02	12
23 Infraorbital suture (trace) √	InfOSut	37	39	0.95	26	55	65	0.85	65
24 Genial pits	GenPit	42	42	1.00	27	42	42	1.00	27
25 Parietal foramina √	ParFor	58	64	0.91	5	95	122	0.78	16

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Eneolithic- Continued										
Traits	Trait Abbreviations	Cranial method			Crania	Side method			Sides/Crania
		n	N	Incidence	Unobservable	n	N	Incidence	Unobservable
26 Obelionic foramen	ObelFor	10	58	0.17	7	10	58	0.17	7
27 Superior sagittal sinus turns right	SSSTR	44	54	0.81	11	44	54	0.81	11
28 Parietal process of temporal √	ParProcT	1	56	0.02	13	1	93	0.01	45
29 Posterior condylar canal patent √	PCondCan	38	45	0.84	24	63	79	0.80	59
30 Accessory lesser palatine foramen √	AccLPalFo	39	47	0.83	22	55	77	0.71	61
31 Zygomaticofacial foramen double √	ZygFacFor	21	58	0.36	11	24	94	0.26	44
32 Supraorbital foramen (complete) √	SupOrbFor	19	62	0.31	7	27	122	0.22	16
33 Frontal foramen or notch √	FroFor	9	60	0.15	9	13	113	0.12	25
34 Accessory supraorbital foramina √	AccSupOFor	3	58	0.05	11	3	109	0.03	25
35 Frontal grooves √	FroGroove	15	52	0.29	17	22	97	0.23	41
36 Supratrochlear notch or canal √	SupTNot	20	58	0.34	7	25	115	0.22	15
37 Accessory infraorbital foramen √	AccInfOFor	13	38	0.34	31	16	59	0.27	79
38 Accessory mental foramen √	AccMentFor	21	52	0.40	17	25	99	0.25	39
39 Ossicle at lambda	OsLam	6	48	0.13	21	6	48	0.13	21
40 Inca bone	IncaB	1	55	0.02	10	1	55	0.02	10
41 Lambdoidal suture ossicle √	LambSutOs	24	54	0.44	15	34	91	0.37	47
42 Ossicle at Asterion √	OsAst	7	51	0.14	14	9	90	0.10	40
43 Bregmatic bone	BregBone	0	47	0.00	22	0	47	0.00	22
44 Coronal suture ossicle √	CorSutOs	4	42	0.10	27	5	72	0.07	66
45 Os sagittal suture	SagSutOs	5	41	0.12	28	5	41	0.12	28
46 Epipteric bone √	EpiBone	7	36	0.19	33	8	58	0.14	80
47 Parietal notch bone √	ParNotBone	13	55	0.24	10	15	93	0.16	37
48 Occipitomastoid suture ossicle √	OccMastSutOs	5	29	0.17	40	5	45	0.11	93
49 Nasal bone variation	NasBone	9	26	0.35	43	9	26	0.35	43
50 Frontotemporal articulation √	FroTempArt	0	47	0.00	22	0	78	0.00	60
51 Condylar facet double (partial) √	CondFacDo	16	51	0.31	18	26	91	0.29	47
52 Rocker jaw	RockJaw	14	44	0.32	25	14	44	0.32	25

<u>Legend:</u> √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Developed Krotovo (Locality 1)

Traits	Abbreviations	Cranial method			Crania	Side method			Sides/Crania
		n	N	Incidence	Unobservable	n	N	Incidence	Unobservable
1 Auditory Torus √	AudTorus	8	69	0.12	1	11	132	0.08	8
2 Marginal foramen/canal √	MargFor	15	78	0.19	5	18	130	0.14	36
3 Precondylar tubercle √	PrecondTub	10	62	0.16	21	13	114	0.11	52
4 Ossified apical ligament	OsApiLig	7	60	0.12	23	7	60	0.12	23
5 Clino-clinoid bridge √	ClinoCBri	3	46	0.07	37	4	73	0.05	93
6 Carotico-clinoid bridge √	CarotCBri	6	47	0.13	36	7	73	0.10	93
7 Paracondylar process √	PCondPro	12	32	0.38	51	14	44	0.32	122
8 Intermediate condylar canal √	IntCondCan	18	51	0.35	32	25	81	0.31	85
9 Anterior condylar canal double √	AntCondCan	20	71	0.28	12	23	123	0.19	43
10 Pterygo-alar bridge (partial) √	PterABr	15	64	0.23	19	21	107	0.20	59
11 Pterygo-spinous bridge (partial) √	PterSBr	5	62	0.08	21	5	99	0.05	67
12 Trochlear spur √	TrochSpur	3	70	0.04	13	3	133	0.02	33
13 Mylohyoid arch √	MylohA	6	64	0.09	19	6	110	0.05	56
14 Lingula bridge √	LingBri	43	62	0.69	21	63	104	0.61	62
15 Genial tubercles	GenTub	59	64	0.92	19	59	64	0.92	19
16 Median mental spine	MMentSp	23	64	0.36	19	23	64	0.36	19
17 Biasterionic suture √	BiAstSut	2	54	0.04	16	4	102	0.04	38
18 Tympanic dehiscence √	TympDeh	15	80	0.19	3	18	151	0.12	15
19 Foramen ovale incomplete √	ForOvInc	4	65	0.06	18	4	105	0.04	61
20 Foramen spinosum open √	ForSpinOp	27	63	0.43	20	39	103	0.38	63
21 Os japonicum (trace) √	OsJap	9	56	0.16	27	12	83	0.14	83
22 Metopism	Metop	2	69	0.03	1	2	69	0.03	1
23 Infraorbital suture (trace) √	InfOSut	46	49	0.94	21	67	79	0.85	61
24 Genial pits	GenPit	60	61	0.98	22	60	61	0.98	22
25 Parietal foramina √	ParFor	65	75	0.87	8	114	147	0.78	19

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Developed Krotovo (Locality 1)- Continued

Traits	Abbreviations	Cranial method n	Cranial method N	Cranial method Incidence	Crania Unobservable	Side method n	Side method N	Side method Incidence	Sides/Crania Unobservable
26 Obelionic foramen	ObelFor	20	61	0.33	9	20	61	0.33	9
27 Superior sagittal sinus turns right	SSSTR	46	58	0.79	12	46	58	0.79	12
28 Parietal process of temporal √	ParProcT	1	62	0.02	21	1	105	0.01	61
29 Posterior condylar canal patent √	PCondCan	47	55	0.85	28	68	84	0.81	82
30 Accessory lesser palatine foramen √	AccLPalFo	41	56	0.73	27	58	84	0.69	82
31 Zygomaticofacial foramen double √	ZygFacFor	22	73	0.30	10	23	116	0.20	50
32 Supraorbital foramen (complete) √	SupOrbFor	11	72	0.15	11	13	141	0.09	25
33 Frontal foramen or notch √	FroFor	19	73	0.26	10	23	140	0.16	26
34 Accessory supraorbital foramina √	AccSupOFor	5	73	0.07	10	5	139	0.04	27
35 Frontal grooves √	FroGroove	13	68	0.19	15	19	124	0.15	34
36 Supratrochlear notch or canal √	SupTNot	11	62	0.18	8	13	120	0.11	20
37 Accessory infraorbital foramen √	AccInfOFor	23	47	0.49	36	34	76	0.45	90
38 Accessory mental foramen √	AccMentFor	27	67	0.40	16	36	127	0.28	39
39 Ossicle at lambda	OsLam	3	55	0.05	28	3	55	0.05	28
40 Inca bone	IncaB	0	55	0.00	15	0	55	0.00	15
41 Lambdoidal suture ossicle √	LambSutOs	21	55	0.38	28	31	103	0.30	63
42 Ossicle at Asterion √	OsAst	6	49	0.12	21	8	86	0.09	54
43 Bregmatic bone	BregBone	0	63	0.00	20	0	63	0.00	20
44 Coronal suture ossicle √	CorSutOs	1	60	0.02	23	1	104	0.01	62
45 Os sagittal suture	SagSutOs	1	44	0.02	39	1	44	0.02	39
46 Epipteric bone √	EpiBone	4	38	0.11	45	5	58	0.09	108
47 Parietal notch bone √	ParNotBone	8	61	0.13	9	11	106	0.10	34
48 Occipitomastoid suture ossicle √	OccMastSutOs	5	38	0.13	45	5	55	0.09	111
49 Nasal bone variation	NasBone	15	41	0.37	42	15	41	0.37	42
50 Frontotemporal articulation √	FroTempArt	0	48	0.00	35	0	80	0.00	86
51 Condylar facet double (partial) √	CondFacDo	21	59	0.36	24	30	99	0.30	67
52 Rocker jaw	RockJaw	18	65	0.28	18	18	65	0.28	18

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Developed Krotovo (Locality 2) Without Kurgan

Traits	Abbreviations	Cranial method			Crania	Side method			Sides/Crania
		n	N	Incidence	Unobservable	n	N	Incidence	Unobservable
1 Auditory Torus √	AudTorus	11	53	0.21	3	13	100	0.13	12
2 Marginal foramen/canal √	MargFor	8	49	0.16	9	11	81	0.14	33
3 Precondylar tubercle √	PrecondTub	7	36	0.19	22	9	68	0.13	48
4 Ossified apical ligament	OsApiLig	7	34	0.21	24	7	34	0.21	23
5 Clino-clinoid bridge √	ClinoCBri	1	23	0.04	35	1	39	0.03	75
6 Carotico-clinoid bridge √	CarotCBri	3	17	0.18	41	4	30	0.13	84
7 Paracondylar process √	PCondPro	11	19	0.58	39	13	30	0.43	86
8 Intermediate condylar canal √	IntCondCan	15	35	0.43	23	20	59	0.34	55
9 Anterior condylar canal double √	AntCondCan	15	43	0.35	15	18	80	0.23	36
10 Pterygo-alar bridge (partial) √	PterABr	6	38	0.16	20	8	59	0.14	57
11 Pterygo-spinous bridge (partial) √	PterSBr	1	33	0.03	25	1	48	0.02	68
12 Trochlear spur √	TrochSpur	2	50	0.04	8	3	91	0.03	25
13 Mylohyoid arch √	MylohA	7	45	0.16	13	9	75	0.12	41
14 Lingula bridge √	LingBri	31	45	0.69	13	48	72	0.67	44
15 Genial tubercles	GenTub	40	44	0.91	14	40	44	0.91	14
16 Median mental spine	MMentSp	14	43	0.33	15	14	43	0.33	15
17 Biasterionic suture √	BiAstSut	5	43	0.12	13	8	78	0.10	34
18 Tympanic dehiscence √	TympDeh	11	54	0.20	4	17	99	0.17	17
19 Foramen ovale incomplete √	ForOvInc	1	38	0.03	20	1	59	0.02	57
20 Foramen spinosum open √	ForSpinOp	16	35	0.46	23	19	53	0.36	63
21 Os japonicum (trace) √	OsJap	3	30	0.10	28	3	41	0.07	75
22 Metopism	Metop	0	51	0.00	5	0	51	0.00	5
23 Infraorbital suture (trace) √	InfOSut	23	25	0.92	31	34	39	0.87	73
24 Genial pits	GenPit	43	44	0.98	14	43	44	0.98	14
25 Parietal foramina √	ParFor	43	50	0.86	8	76	93	0.82	23

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Developed Krotovo (Locality 2) Without Kurgan - Continued

Traits	Abbreviations	Cranial method			Crania	Side method			Sides/Crania
		n	N	Incidence	Unobservable	n	N	Incidence	Unobservable
26 Obelionic foramen	ObelFor	12	44	0.27	12	12	44	0.27	12
27 Superior sagittal sinus turns right	SSSTR	33	42	0.79	14	33	42	0.79	14
28 Parietal process of temporal √	ParProcT	1	44	0.02	14	1	67	0.01	47
29 Posterior condylar canal patent √	PCondCan	25	35	0.71	23	36	59	0.61	57
30 Accessory lesser palatine foramen √	AccLPalFo	22	32	0.69	26	32	51	0.63	65
31 Zygomaticofacial foramen double √	ZygFacFor	10	42	0.24	16	13	62	0.21	54
32 Supraorbital foramen (complete) √	SupOrbFor	9	53	0.17	5	12	97	0.12	19
33 Frontal foramen or notch √	FroFor	10	52	0.19	6	11	91	0.12	25
34 Accessory supraorbital foramina √	AccSupOFor	2	49	0.04	9	3	86	0.03	24
35 Frontal grooves √	FroGroove	12	46	0.26	12	17	82	0.21	30
36 Supratrochlear notch or canal √	SupTNot	12	50	0.24	6	13	94	0.14	18
37 Accessory infraorbital foramen √	AccInfOFor	10	24	0.42	34	12	38	0.32	78
38 Accessory mental foramen √	AccMentFor	15	46	0.33	12	18	83	0.22	33
39 Ossicle at lambda	OsLam	3	41	0.07	17	3	41	0.07	17
40 Inca bone	IncaB	2	42	0.05	14	2	42	0.05	14
41 Lambdoidal suture ossicle √	LambSutOs	18	40	0.45	18	26	73	0.36	43
42 Ossicle at Asterion √	OsAst	3	40	0.08	16	3	68	0.04	44
43 Bregmatic bone	BregBone	0	45	0.00	13	0	45	0.00	13
44 Coronal suture ossicle √	CorSutOs	2	42	0.05	16	2	75	0.03	41
45 Os sagittal suture	SagSutOs	0	32	0.00	26	0	32	0.00	26
46 Epipteric bone √	EpiBone	4	22	0.18	36	4	34	0.12	82
47 Parietal notch bone √	ParNotBone	7	40	0.18	16	8	68	0.12	44
48 Occipitomastoid suture ossicle √	OccMastSutOs	2	28	0.07	30	2	44	0.05	72
49 Nasal bone variation	NasBone	10	18	0.56	40	10	18	0.56	40
50 Frontotemporal articulation √	FroTempArt	1	28	0.04	30	1	46	0.02	70
51 Condylar facet double (partial) √	CondFacDo	5	37	0.14	21	7	64	0.11	52
52 Rocker jaw	RockJaw	16	36	0.44	22	16	36	0.44	22

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Developed Krotovo (Locality 2) With Kurgan

Traits	Abbreviations	Cranial method			Crania	Side method			Sides/Crania
		n	N	Incidence	Unobservable	n	N	Incidence	Unobservable
1 Auditory Torus √	AudTorus	5	37	0.14	3	8	73	0.11	7
2 Marginal foramen/canal √	MargFor	7	33	0.21	8	12	63	0.19	19
3 Precondylar tubercle √	PrecondTub	11	29	0.38	12	17	54	0.31	28
4 Ossified apical ligament	OsApiLig	4	26	0.15	15	4	26	0.15	15
5 Clino-clinoid bridge √	ClinoCBri	5	27	0.19	14	5	50	0.10	32
6 Carotico-clinoid bridge √	CarotCBri	8	24	0.33	17	9	40	0.23	42
7 Paracondylar process √	PCondPro	9	19	0.47	22	11	29	0.38	53
8 Intermediate condylar canal √	IntCondCan	17	31	0.55	10	26	52	0.50	30
9 Anterior condylar canal double √	AntCondCan	11	34	0.32	7	17	60	0.28	22
10 Pterygo-alar bridge (partial) √	PterABr	9	28	0.32	13	14	50	0.28	32
11 Pterygo-spinous bridge (partial) √	PterSBr	5	29	0.17	12	5	49	0.10	33
12 Trochlear spur √	TrochSpur	4	36	0.11	5	7	71	0.10	11
13 Mylohyoid arch √	MylohA	2	29	0.07	12	3	52	0.06	30
14 Lingula bridge √	LingBri	18	29	0.62	12	28	51	0.55	31
15 Genial tubercles	GenTub	27	27	1.00	14	27	27	1.00	14
16 Median mental spine	MMentSp	8	28	0.29	13	8	28	0.29	13
17 Biasterionic suture √	BiAstSut	5	34	0.15	6	8	62	0.13	18
18 Tympanic dehiscence √	TympDeh	5	35	0.14	6	5	69	0.07	13
19 Foramen ovale incomplete √	ForOvInc	2	28	0.07	13	3	48	0.06	34
20 Foramen spinosum open √	ForSpinOp	10	29	0.34	12	15	51	0.29	31
21 Os japonicum (trace) √	OsJap	4	27	0.15	14	4	41	0.10	41
22 Metopism	Metop	1	39	0.03	1	1	39	0.03	1
23 Infraorbital suture (trace) √	InfOSut	27	27	1.00	13	42	46	0.91	34
24 Genial pits	GenPit	27	27	1.00	14	27	27	1.00	14
25 Parietal foramina √	ParFor	31	36	0.86	5	56	71	0.79	11

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Developed Krotovo (Locality 2) With Kurgan - Continued

Traits	Trait Abbreviations	Cranial method n	Cranial method N	Cranial method Incidence	Crania Unobservable	Side method n	Side method N	Side method Incidence	Sides/Crania Unobservable
26 Obelionic foramen	ObelFor	9	36	0.25	4	9	36	0.25	4
27 Superior sagittal sinus turns right	SSSTR	26	36	0.72	4	26	36	0.72	4
28 Parietal process of temporal √	ParProcT	0	35	0.00	6	0	59	0.00	23
29 Posterior condylar canal patent √	PCondCan	22	29	0.76	12	29	46	0.63	36
30 Accessory lesser palatine foramen √	AccLPalFo	30	32	0.94	9	47	58	0.81	24
31 Zygomaticofacial foramen double √	ZygFacFor	7	30	0.23	11	8	51	0.16	31
32 Supraorbital foramen (complete) √	SupOrbFor	5	37	0.14	4	9	73	0.12	9
33 Frontal foramen or notch √	FroFor	10	37	0.27	4	16	71	0.23	11
34 Accessory supraorbital foramina √	AccSupOFor	5	35	0.14	6	5	67	0.07	11
35 Frontal grooves √	FroGroove	6	36	0.17	5	8	67	0.12	15
36 Supratrochlear notch or canal √	SupTNot	8	37	0.22	3	10	72	0.14	8
37 Accessory infraorbital foramen √	AccInfOFor	4	24	0.17	17	6	42	0.14	40
38 Accessory mental foramen √	AccMentFor	9	32	0.28	9	12	57	0.21	25
39 Ossicle at lambda	OsLam	0	34	0.00	7	0	34	0.00	7
40 Inca bone	IncaB	1	36	0.03	4	1	36	0.03	4
41 Lambdoidal suture ossicle √	LambSutOs	14	32	0.44	9	24	60	0.40	22
42 Ossicle at Asterion √	OsAst	4	30	0.13	10	5	55	0.09	25
43 Bregmatic bone	BregBone	0	33	0.00	8	0	33	0.00	8
44 Coronal suture ossicle √	CorSutOs	0	31	0.00	10	0	57	0.00	25
45 Os sagittal suture	SagSutOs	1	25	0.04	16	1	25	0.04	16
46 Epipteric bone √	EpiBone	5	20	0.25	21	6	33	0.18	49
47 Parietal notch bone √	ParNotBone	8	34	0.24	6	9	60	0.15	20
48 Occipitomastoid suture ossicle √	OccMastSutOs	4	25	0.16	16	4	42	0.10	40
49 Nasal bone variation	NasBone	8	18	0.44	23	8	18	0.44	23
50 Frontotemporal articulation √	FroTempArt	0	26	0.00	15	0	46	0.00	36
51 Condylar facet double (partial) √	CondFacDo	5	32	0.16	9	9	53	0.17	29
52 Rocker jaw	RockJaw	12	26	0.46	15	12	26	0.46	15

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Late Krotovo Developed Bronze		Cranial method			Crania	Side method			Sides/Crania
Traits	Abbreviations	n	N	Incidence	Unobservable	n	N	Incidence	Unobservable
1 Auditory Torus √	AudTorus	3	37	0.08	1	3	71	0.04	5
2 Marginal foramen/canal √	MargFor	9	36	0.25	2	13	65	0.20	11
3 Precondylar tubercle √	PrecondTub	7	31	0.23	7	11	58	0.19	18
4 Ossified apical ligament	OsApiLig	1	28	0.04	10	1	28	0.04	10
5 Clino-clinoid bridge √	ClinoCBri	1	26	0.04	12	2	48	0.04	28
6 Carotico-clinoid bridge √	CarotCBri	1	24	0.04	14	2	45	0.04	31
7 Paracondylar process √	PCondPro	10	23	0.43	15	14	41	0.34	35
8 Intermediate condylar canal √	IntCondCan	11	27	0.41	11	14	46	0.30	30
9 Anterior condylar canal double √	AntCondCan	7	31	0.23	7	9	59	0.15	17
10 Pterygo-alar bridge (partial) √	PterABr	6	33	0.18	5	6	57	0.11	19
11 Pterygo-spinous bridge (partial) √	PterSBr	6	32	0.19	6	8	55	0.15	21
12 Trochlear spur √	TrochSpur	4	37	0.11	1	6	71	0.08	5
13 Mylohyoid arch √	MylohA	4	32	0.13	6	7	60	0.12	16
14 Lingula bridge √	LingBri	19	32	0.59	6	32	59	0.54	17
15 Genial tubercles	GenTub	25	28	0.89	10	25	28	0.89	10
16 Median mental spine	MMentSp	9	28	0.32	10	9	28	0.32	10
17 Biasterionic suture √	BiAstSut	7	35	0.20	3	9	66	0.14	10
18 Tympanic dehiscence √	TympDeh	9	36	0.25	2	14	69	0.20	7
19 Foramen ovale incomplete √	ForOvInc	2	33	0.06	5	2	56	0.04	20
20 Foramen spinosum open √	ForSpinOp	18	33	0.55	5	24	56	0.43	20
21 Os japonicum (trace) √	OsJap	3	30	0.10	8	4	52	0.08	24
22 Metopism	Metop	1	38	0.03	0	1	38	0.03	0
23 Infraorbital suture (trace) √	InfOSut	22	24	0.92	14	35	43	0.81	33
24 Genial pits	GenPit	27	27	1.00	11	27	27	1.00	11
25 Parietal foramina √	ParFor	29	37	0.78	1	49	72	0.68	4

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Late Krotovo Developed Bronze - Continued										
	Trait	Cranial method			Crania	Side method			Sides/Crania
Traits	Abbreviations	n	N	Incidence	Unobservable	n	N	Incidence	Unobservable
26 Obelionic foramen	ObelFor	9	35	0.26	3	9	35	0.26	3
27 Superior sagittal sinus turns right	SSSTR	27	35	0.77	3	27	35	0.77	3
28 Parietal process of temporal √	ParProcT	1	34	0.03	4	2	63	0.03	13
29 Posterior condylar canal patent √	PCondCan	20	27	0.74	11	27	47	0.57	29
30 Accessory lesser palatine foramen √	AccLPalFo	25	31	0.81	7	41	52	0.79	24
31 Zygomaticofacial foramen double √	ZygFacFor	9	34	0.26	4	12	60	0.20	16
32 Supraorbital foramen (complete) √	SupOrbFor	7	36	0.19	2	8	72	0.11	4
33 Frontal foramen or notch √	FroFor	3	37	0.08	1	3	72	0.04	4
34 Accessory supraorbital foramina √	AccSupOFor	1	37	0.03	1	1	72	0.01	4
35 Frontal grooves √	FroGroove	10	38	0.26	0	12	73	0.16	3
36 Supratrochlear notch or canal √	SupTNot	8	37	0.22	1	11	73	0.15	3
37 Accessory infraorbital foramen √	AccInfOFor	10	21	0.48	17	15	39	0.38	37
38 Accessory mental foramen √	AccMentFor	10	33	0.30	5	11	66	0.17	10
39 Ossicle at lambda	OsLam	1	31	0.03	7	1	31	0.03	7
40 Inca bone	IncaB	0	35	0.00	3	0	35	0.00	3
41 Lambdoidal suture ossicle √	LambSutOs	13	32	0.41	6	19	58	0.33	18
42 Ossicle at Asterion √	OsAst	8	32	0.25	6	9	56	0.16	20
43 Bregmatic bone	BregBone	0	32	0.00	6	0	32	0.00	6
44 Coronal suture ossicle √	CorSutOs	0	28	0.00	10	0	54	0.00	22
45 Os sagittal suture	SagSutOs	2	28	0.07	10	2	28	0.07	10
46 Epipteric bone √	EpiBone	3	23	0.13	15	4	42	0.10	34
47 Parietal notch bone √	ParNotBone	6	32	0.19	6	6	60	0.10	16
48 Occipitomastoid suture ossicle √	OccMastSutOs	2	22	0.09	16	2	42	0.05	34
49 Nasal bone variation	NasBone	5	18	0.28	20	5	18	0.28	20
50 Frontotemporal articulation √	FroTempArt	1	26	0.04	12	1	48	0.02	28
51 Condylar facet double (partial) √	CondFacDo	15	31	0.48	7	23	55	0.42	21
52 Rocker jaw	RockJaw	17	30	0.57	8	17	30	0.57	8

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Andronovo Developed Bronze										
		Cranial method			Crania	Side method			Sides/Crania
Traits	Abbreviations	n	N	Incidence	Unobservable	n	N	Incidence	Unobservable
1 Auditory Torus √	AudTorus	6	19	0.32	0	8	35	0.23	3
2 Marginal foramen/canal √	MargFor	2	18	0.11	1	2	30	0.07	8
3 Precondylar tubercle √	PrecondTub	4	12	0.33	7	6	23	0.26	15
4 Ossified apical ligament	OsApiLig	2	10	0.20	9	2	10	0.20	9
5 Clino-clinoid bridge √	ClinoCBri	0	12	0 00	7	0	22	0.00	16
6 Carotico-clinoid bridge √	CarotCBri	2	12	0.17	7	3	20	0.15	18
7 Paracondylar process √	PCondPro	2	9	0.22	10	3	16	0.19	22
8 Intermediate condylar canal √	IntCondCan	7	11	0.64	8	12	20	0.60	18
9 Anterior condylar canal double √	AntCondCan	3	13	0.23	6	4	24	0.17	14
10 Pterygo-alar bridge (partial) √	PterABr	4	16	0.25	3	4	27	0.15	11
11 Pterygo-spinous bridge (partial) √	PterSBr	1	16	0.06	3	1	26	0.04	12
12 Trochlear spur √	TrochSpur	1	17	0.06	2	1	31	0.03	7
13 Mylohyoid arch √	MylohA	2	14	0.14	5	3	27	0.11	11
14 Lingula bridge √	LingBri	12	14	0.86	5	20	25	0.80	13
15 Genial tubercles	GenTub	10	14	0.71	5	10	14	0.71	5
16 Median mental spine	MMentSp	7	15	0.47	4	7	15	0.47	4
17 Biasterionic suture √	BiAstSut	2	17	0.12	2	4	31	0.13	7
18 Tympanic dehiscence √	TympDeh	3	19	0.16	0	5	33	0.15	5
19 Foramen ovale incomplete √	ForOvInc	1	16	0.06	3	2	27	0.07	11
20 Foramen spinosum open √	ForSpinOp	6	16	0.38	3	9	26	0.35	12
21 Os japonicum (trace) √	OsJap	0	14	0.00	5	0	22	0.00	16
22 Metopism	Metop	0	18	0.00	1	0	18	0.00	1
23 Infraorbital suture (trace) √	InfOSut	11	14	0.79	5	15	21	0.71	17
24 Genial pits	GenPit	13	14	0.93	5	13	14	0.93	5
25 Parietal foramina √	ParFor	13	19	0.68	0	18	36	0.50	2

Legend: √ - bilateral nonmetric variant

APPENDIX B - CONTINUED

Andronovo Developed Bronze - Continued

Traits	Trait Abbreviations	Cranial method n	Cranial method N	Cranial method Incidence	Crania Unobservable	Side method n	Side method N	Side method Incidence	Sides/Crania Unobservable
26 Obelionic foramen	ObelFor	5	16	0.31	3	5	16	0.31	3
27 Superior sagittal sinus turns right	SSSTR	13	18	0.72	1	13	18	0.72	1
28 Parietal process of temporal √	ParProcT	0	16	0.00	3	0	27	0.00	11
29 Posterior condylar canal patent √	PCondCan	8	11	0.73	8	12	19	0.63	19
30 Accessory lesser palatine foramen √	AccLPalFo	13	13	1.00	6	20	22	0.91	16
31 Zygomaticofacial foramen double √	ZygFacFor	6	17	0.35	2	9	30	0.30	8
32 Supraorbital foramen (complete) √	SupOrbFor	6	18	0.33	1	7	35	0.20	3
33 Frontal foramen or notch √	FroFor	6	18	0.33	1	7	35	0.20	3
34 Accessory supraorbital foramina √	AccSupOFor	1	17	0.06	2	1	33	0.03	3
35 Frontal grooves √	FroGroove	6	16	0.38	3	9	32	0.28	6
36 Supratrochlear notch or canal √	SupTNot	4	18	0.22	1	5	35	0.14	3
37 Accessory infraorbital foramen √	AccInfOFor	1	13	0.08	6	2	21	0.10	17
38 Accessory mental foramen √	AccMentFor	6	15	0.40	4	8	27	0.30	11
39 Ossicle at lambda	OsLam	0	15	0.00	4	0	15	0.00	4
40 Inca bone	IncaB	0	19	0.00	0	0	19	0.00	0
41 Lambdoidal suture ossicle √	LambSutOs	8	16	0.50	3	9	32	0.28	6
42 Ossicle at Asterion √	OsAst	4	17	0.24	2	4	29	0.14	9
43 Bregmatic bone	BregBone	0	15	0.00	4	0	15	0.00	4
44 Coronal suture ossicle √	CorSutOs	1	15	0.07	4	1	27	0.04	11
45 Os sagittal suture	SagSutOs	0	14	0.00	5	0	14	0.00	5
46 Epipteric bone √	EpiBone	2	11	0.18	8	3	18	0.17	20
47 Parietal notch bone √	ParNotBone	5	19	0.26	0	5	31	0.16	7
48 Occipitomastoid suture ossicle √	OccMastSutOs	0	9	0.00	10	0	15	0.00	23
49 Nasal bone variation	NasBone	7	13	0.54	6	7	13	0.54	6
50 Frontotemporal articulation √	FroTempArt	1	11	0.09	8	2	19	0.11	19
51 Condylar facet double (partial) √	CondFacDo	2	10	0.20	9	3	18	0.17	20
52 Rocker jaw	RockJaw	5	14	0.36	5	5	14	0.36	5

Legend: √ - bilateral nonmetric variant

APPENDIX C - THE SEX DATA AND THE CHI-SQUARED VALUES FOR SEX DIFFERENCES IN TRAIT FREQUENCY FOR 36 NONMETRIC VARIANTS

Pooled Sample of Siberian Crania

Traits	Female n	Female N	Female Freq	Male n	Male N	Male Freq	Unknown n	Unknown N	Unknown Freq	Chi-square (sex difference in trait freq)	p	Fisher's Exact
2 MargFor	30	181	16.57	36	291	12.37	2	18	11.11	1.639	0.200	-
3 PrecondTub	33	145	22.76	41	261	15.71	1	10	10.00	3.108	0.078	-
4 OsApiLig	6	74	8.11	21	127	16.54	0	5	0.00	2.177*	0.140	-
5 ClinoCBri	3	104	2.88	12	182	6.59	2	6	33.33	1.162*	0.281	-
8 IntCondCan	46	127	36.22	78	195	40.00	5	11	45.45	0.464	0.496	-
9 AntCondCan	37	167	22.16	51	266	19.17	3	11	27.27	0.056	0.453	-
10 PterABr	19	146	13.01	49	240	20.42	3	12	25.00	3.428	0.064	-
11 PterSBr	4	133	3.01	22	225	9.78	0	12	0.00	4.728*	0.030†	-
12 TrochSpur	8	181	4.42	23	313	7.35	1	19	5.26	1.672	0.196	-
13 MylohA	11	147	7.48	23	258	8.91	0	16	0.00	0.250	0.617	-
14 LingBri	88	142	61.97	149	254	58.66	7	15	46.67	0.415	0.519	-
18 TympDeh	31	203	15.27	34	322	10.56	1	20	5.00	2.548	0.110	-
19 ForOvInc	6	145	4.14	12	235	5.11	0	12	0.00	0.034*	0.855	-
20 ForSpinOp	59	135	43.70	66	233	28.33	9	13	69.23	9.011	0.003†	-
21 OsJap	9	101	8.91	23	204	11.27	1	13	7.69	0.402	0.526	-
22 Metop	2	98	2.04	3	162	1.85	0	8	0.00	0.000*	1.000	-
24 GenPit	77	78	98.72	128	130	98.46	7	7	100.00	0.000*	1.000	-
25 ParFor	152	208	73.08	247	316	78.16	9	17	52.94	1.787	0.181	-
27 SSSTR	73	93	78.49	110	143	76.92	6	7	85.71	0.080	0.777	-
28 ParProcT	1	150	0.67	4	253	1.58	0	11	0.00	0.113*	0.737	-
31 ZygFacFor	30	135	22.22	54	264	20.45	5	14	35.71	0.168	0.682	-
32 SupOrbFor	21	192	10.94	49	329	14.89	6	19	31.58	1.632	0.201	-
34 AccSupOFor	7	178	3.93	11	311	3.54	0	17	0.00	0.000*	1.000	-
37 AccInfOFor	22	90	24.44	63	177	35.59	0	8	0.00	3.417	0.065	-
39 OsLam	4	86	4.65	9	131	6.87	0	7	0.00	0.145*	0.703	-
40 IncaB	1	89	1.12	3	145	2.07	0	8	0.00	0.000*	0.982	-
41 LambSutOs	52	158	32.91	87	242	35.95	4	17	23.53	0.389	0.533	-
42 OsAst	9	136	6.62	28	234	11.97	1	14	7.14	2.734	0.098	-
43 BregBone	0	87	0.00	0	141	0.00	0	7	0.00	-	-	-
44 CorSutOs	3	146	2.05	6	232	2.59	0	11	0.00	0.000*	1.000	-
45 SagSutOs	0	81	0.00	9	98	9.18	0	5	0.00	6.027*	0.014†	-
46 EpiBone	6	83	7.23	24	153	15.69	0	7	0.00	3.469	0.063	-
48 OcMastSutOs	4	93	4.30	14	142	9.86	0	8	0.00	1.732*	0.188	-
50 FroTempArt	3	117	2.56	0	193	0.00	1	7	14.29	2.680*	0.102	-
51 CondFacDo	33	137	24.09	65	233	27.90	0	10	0.00	0.643	0.423	-
52 RockJaw	36	73	49.32	42	133	31.58	4	9	44.44	6.302	0.012†	-

Legend: *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX C - CONTINUED

Eneolithic												
	Female			Male			Unknown			Chi-square (sex difference		Fisher's
Traits	n	N	Freq	n	N	Freq	n	N	Freq	in trait freq)	p	Exact
2 MargFor	6	36	16.67	6	84	7.14	0	1	0.00	1.592*	0.207	-
3 PrecondTub	7	28	25.00	12	71	16.90	0	0	-	0.407*	0.523	-
4 OsApiLig	1	13	7.69	5	35	14.29	0	0	-	0.015*	0.902	-
5 ClinoCBri	0	16	0.00	5	44	11.36	0	0	-	0.775*	0.379	-
8 IntCondCan	8	21	38.10	24	54	44.44	0	0	-	0.057*	0.811	-
9 AntCondCan	5	31	16.13	15	67	22.39	0	0	-	0.198*	0.656	-
10 PterABr	6	25	24.00	12	72	16.67	0	1	0.00	0.264*	0.607	-
11 PterSBr	0	24	0.00	6	69	8.70	0	0	-	1.023*	0.312	-
12 TrochSpur	1	32	3.13	10	82	12.20	1	2	50.00	1.256*	0.262	-
13 MylohA	2	26	7.69	4	69	5.80	0	2	0.00	0.000*	1.000	-
14 LingBri	14	28	50.00	39	70	55.71	0	2	0.00	0.263	0.608	-
18 TympDeh	1	35	2.86	6	88	6.82	0	1	0.00	0.180*	0.671	-
19 ForOvInc	1	25	4.00	5	71	7.04	0	1	0.00	0.004*	0.952	-
20 ForSpinOp	8	22	36.36	19	69	27.54	1	1	100.00	0.272*	0.602	-
21 OsJap	3	17	17.65	6	61	9.84	1	1	100.00	0.214*	0.644	-
22 Metop	0	15	0.00	1	38	2.63	0	0	-	0.000*	1.000	-
24 GenPit	9	9	100.00	32	32	100.00	1	1	100.00	-	-	-
25 ParFor	27	35	77.14	67	86	77.91	1	1	100.00	0.000*	1.000	-
27 SSSTR	13	16	81.25	31	38	81.58	0	0	-	0.000*	1.000	-
28 ParProcT	1	23	4.35	0	69	0.00	0	1	0.00	0.337*	0.562	-
31 ZygFacFor	7	23	30.43	16	70	22.86	1	1	100.00	0.205*	0.651	-
32 SupOrbFor	6	33	18.18	20	87	22.99	1	2	50.00	0.104*	0.747	-
34 AccSupOFor	0	27	0.00	3	80	3.75	0	2	0.00	0.120*	0.729	-
37 AccInfOFor	5	13	38.46	11	46	23.91	0	0	-	0.474*	0.491	-
39 OsLam	1	13	7.69	5	35	14.29	0	0	-	0.015*	0.902	-
40 IncaB	0	15	0.00	1	40	2.50	0	0	-	0.000*	1.000	-
41 LambSutOs	7	24	29.17	27	66	40.91	0	1	0.00	0.593*	0.441	-
42 OsAst	2	22	9.09	7	68	10.29	0	0	-	0.000*	1.000	-
43 BregBone	0	13	0.00	0	34	0.00	0	0	-	-	-	-
44 CorSutOs	1	19	5.26	4	52	7.69	0	1	0.00	0.000*	1.000	-
45 SagSutOs	0	11	0.00	5	30	16.67	0	0	-	0.822*	0.365	-
46 EpiBone	0	10	0.00	8	47	17.02	0	1	0.00	0.821*	0.365	-
48 OcMastSutOs	0	10	0.00	5	35	14.29	0	0	-	0.486*	0.486	-
50 FroTempArt	0	16	0.00	0	61	0.00	0	1	0.00	-	-	-
51 CondFacDo	8	26	30.77	18	65	27.69	0	0	-	0.001*	0.971	-
52 RockJaw	5	13	38.46	9	30	30.00	0	1	0.00	0.036*	0.850	-

Legend: *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX C - CONTINUED

Developed Krotovo (Locality 1)												
	Female			Male			Unknown			Chi-square (sex difference		Fisher's
Traits	n	N	Freq	n	N	Freq	n	N	Freq	in trait freq)	p	Exact
2 MargFor	8	41	19.51	9	81	11.11	1	8	12.50	0.978*	0.323	-
3 PrecondTub	1	37	2.70	11	73	15.07	1	4	25.00	2.696*	0.101	-
4 OsApiLig	0	21	0.00	7	37	18.92	0	2	0.00	2.911*	0.088	-
5 ClinoCBri	0	26	0.00	2	45	4.44	2	2	100.00	0.120*	0.729	-
8 IntCondCan	8	32	25.00	13	44	29.55	4	5	80.00	0.032*	0.859	-
9 AntCondCan	8	41	19.51	14	77	18.18	1	5	20.00	0.000*	1.000	-
10 PterABr	1	39	2.56	17	64	26.56	3	4	75.00	8.085*	0.004†	-
11 PterSBr	2	37	5.41	3	57	5.26	0	5	0.00	0.000*	1.000	-
12 TrochSpur	2	40	5.00	1	90	1.11	0	3	0.00	0.533*	0.465	-
13 MylohA	4	31	12.90	2	74	2.70	0	5	0.00	2.538*	0.111	-
14 LingBri	22	28	78.57	37	71	52.11	4	5	80.00	5.838	0.016†	-
18 TympDeh	7	49	14.29	11	94	11.70	0	8	0.00	0.031*	0.860	-
19 ForOvInc	2	38	5.26	2	63	3.17	0	4	0.00	0.000*	1.000	-
20 ForSpinOp	21	38	55.26	14	60	23.33	4	5	80.00	10.331	0.001†	-
21 OsJap	4	24	16.67	8	55	14.55	0	4	0.00	0.000*	1.000	-
22 Metop	1	21	4.76	1	47	2.13	0	1	0.00	0.000*	1.000	-
24 GenPit	17	18	94.44	41	41	100.00	2	2	100.00	0.182*	0.669	-
25 ParFor	42	53	79.25	70	90	77.78	2	4	50.00	0.042	0.837	-
27 SSSTR	16	20	80.00	30	37	81.08	0	1	0.00	0.000*	1.000	-
28 ParProcT	0	38	0.00	1	65	1.54	0	2	0.00	0.000*	1.000	-
31 ZygFacFor	5	31	16.13	17	81	20.99	1	4	25.00	0.098*	0.754	-
32 SupOrbFor	5	43	11.63	7	95	7.37	1	3	33.33	0.246*	0.620	-
34 AccSupOFor	1	42	2.38	4	94	4.26	0	3	0.00	0.002*	0.965	-
37 AccInfOFor	10	23	43.48	24	51	47.06	0	2	0.00	0.082	0.775	-
39 OsLam	1	19	5.26	2	33	6.06	0	3	0.00	0.000*	1.000	-
40 IncaB	0	19	0.00	0	35	0.00	0	1	0.00	-	-	-
41 LambSutOs	11	35	31.43	20	62	32.26	0	6	0.00	0.007	0.933	-
42 OsAst	1	27	3.70	6	57	10.53	1	2	50.00	0.402*	0.526	-
43 BregBone	0	21	0.00	0	41	0.00	0	1	0.00	-	-	-
44 CorSutOs	0	35	0.00	1	67	1.49	0	2	0.00	0.000*	1.000	-
45 SagSutOs	0	19	0.00	1	24	4.17	0	1	0.00	0.000*	1.000	-
46 EpiBone	0	20	0.00	5	36	13.89	0	2	0.00	1.581*	0.209	-
48 OcMastSutOs	2	24	8.33	3	28	10.71	0	3	0.00	0.000*	1.000	-
50 FroTempArt	0	28	0.00	0	50	0.00	0	2	0.00	-	-	-
51 CondFacDo	10	34	29.41	20	61	32.79	0	4	0.00	0.115	0.734	-
52 RockJaw	7	18	38.89	11	44	25.00	0	3	0.00	0.617*	0.432	-

Legend: Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX C - CONTINUED

Developed Krotovo (Locality 2) Without Kurgan												
	Female			Male			Unknown			Chi-square (sex difference		Fisher's
Traits	n	N	Freq	n	N	Freq	n	N	Freq	in trait freq)	p	Exact
2 MargFor	7	46	15.22	4	32	12.50	0	3	0.00	0.000*	0.993	-
3 PrecondTub	7	34	20.59	2	32	6.25	0	2	0.00	1.789*	0.181	-
4 OsApiLig	4	18	22.22	3	15	20.00	0	1	0.00	-	-	1.000
5 ClinoCBri	0	17	0.00	1	22	4.55	0	0	-	-	-	1.000
8 IntCondCan	11	33	33.33	9	24	37.50	0	2	0.00	0.002*	0.965	-
9 AntCondCan	12	43	27.91	6	35	17.14	0	2	0.00	0.726*	0.394	-
10 PterABr	5	33	15.15	3	26	11.54	0	0	-	0.000*	0.984	-
11 PterSBr	0	24	0.00	1	24	4.17	0	0	-	0.000*	1.000	-
12 TrochSpur	2	47	4.26	1	40	2.50	0	4	0.00	0.000*	1.000	-
13 MylohA	1	36	2.78	8	37	21.62	0	2	0.00	4.378*	0.036†	-
14 LingBri	22	35	62.86	25	35	71.43	1	2	50.00	0.583	0.445	-
18 TympDeh	8	56	14.29	9	40	22.50	0	3	0.00	0.590*	0.442	-
19 ForOvInc	1	33	3.03	0	26	0.00	0	0	-	0.000*	1.000	-
20 ForSpinOp	11	27	40.74	8	26	30.77	0	0	-	0.221*	0.638	-
21 OsJap	0	21	0.00	3	19	15.79	0	1	0.00	-	-	0.098
22 Metop	0	27	0.00	0	22	0.00	0	2	0.00	-	-	-
24 GenPit	24	24	100.00	18	19	94.74	1	1	100.00	0.014*	0.906	-
25 ParFor	38	51	74.51	35	39	89.74	3	3	100.00	2.427*	0.119	-
27 SSSTR	18	22	81.82	13	18	72.22	2	2	100.00	-	-	0.705
28 ParProcT	0	37	0.00	1	27	3.70	0	3	0.00	0.025*	0.873	-
31 ZygFacFor	8	32	25.00	5	28	17.86	0	2	0.00	0.127*	0.722	-
32 SupOrbFor	5	50	10.00	5	43	11.63	2	4	50.00	0.000*	1.000	-
34 AccSupOFor	3	44	6.82	0	38	0.00	0	4	0.00	1.103*	0.294	-
37 AccInfOFor	4	20	20.00	8	18	44.44	0	0	-	1.611*	0.204	-
39 OsLam	1	23	4.35	2	17	11.76	0	1	0.00	-	-	0.565
40 IncaB	1	20	5.00	1	20	5.00	0	2	0.00	0.000*	1.000	-
41 LambSutOs	14	40	35.00	12	30	40.00	0	3	0.00	0.184	0.668	-
42 OsAst	0	33	0.00	3	31	9.68	0	4	0.00	1.535*	0.215	-
43 BregBone	0	23	0.00	0	20	0.00	0	2	0.00	-	-	-
44 CorSutOs	2	41	4.88	0	33	0.00	0	1	0.00	0.319*	0.572	-
45 SagSutOs	0	20	0.00	0	11	0.00	0	1	0.00	-	-	-
46 EpiBone	2	19	10.53	2	15	13.33	0	0	-	-	-	1.000
48 OcMastSutOs	0	21	0.00	2	21	9.52	0	2	0.00	0.525*	0.469	-
50 FroTempArt	1	28	3.57	0	18	0.00	0	0	-	-	-	1.000
51 CondFacDo	6	32	18.75	1	30	3.33	0	2	0.00	2.296*	0.130	-
52 RockJaw	8	17	47.06	7	18	38.89	1	1	100.00	0.021*	0.884	-

Legend: *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX C - CONTINUED

Developed Krotovo (Locality 2) With Kurgan												
	Female			Male			Unknown			Chi-square (sex difference		Fisher's
Traits	n	N	Freq	n	N	Freq	n	N	Freq	in trait freq)	p	Exact
2 MargFor	3	19	15.79	8	42	19.05	1	2	50.00	0.000*	1.000	-
3 PrecondTub	8	15	53.33	9	37	24.32	0	2	0.00	2.870*	0.090	-
4 OsApiLig	1	8	12.50	3	17	17.65	0	1	0.00	-	-	1.000
5 ClinoCBri	1	15	6.67	4	33	12.12	0	2	0.00	0.004*	0.949	-
8 IntCondCan	9	16	56.25	16	34	47.06	1	2	50.00	0.092*	0.762	-
9 AntCondCan	5	20	25.00	10	38	26.32	2	2	100.00	0.000*	1.000	-
10 PterABr	4	15	26.67	10	33	30.30	0	2	0.00	0.000*	1.000	-
11 PterSBr	1	15	6.67	4	32	12.50	0	2	0.00	0.009*	0.923	-
12 TrochSpur	3	24	12.50	4	45	8.89	0	2	0.00	0.003*	0.956	-
13 MylohA	0	17	0.00	3	33	9.09	0	2	0.00	0.427*	0.513	-
14 LingBri	11	17	64.71	16	33	48.48	1	1	100.00	0.625*	0.429	-
18 TympDeh	1	20	5.00	3	47	6.38	1	2	50.00	0.000*	1.000	-
19 ForOvInc	2	15	13.33	1	31	3.23	0	2	0.00	0.442*	0.506	-
20 ForSpinOp	4	15	26.67	9	34	26.47	2	2	100.00	0.000*	1.000	-
21 OsJap	1	9	11.11	3	30	10.00	0	2	0.00	-	-	1.000
22 Metop	0	13	0.00	1	25	4.00	0	1	0.00	-	-	1.000
24 GenPit	7	7	100.00	19	19	100.00	1	1	100.00	-	-	-
25 ParFor	21	23	91.30	33	46	71.74	2	2	100.00	2.396*	0.122	-
27 SSSTR	9	12	75.00	16	23	69.57	1	1	100.00	-	-	1.000
28 ParProcT	0	17	0.00	0	40	0.00	0	2	0.00	-	-	-
31 ZygFacFor	1	14	7.14	6	35	17.14	1	2	50.00	0.204*	0.651	-
32 SupOrbFor	0	24	0.00	7	47	14.89	2	2	100.00	2.467*	0.116	-
34 AccSupOFor	2	23	8.70	3	44	6.82	0	0	-	0.000*	1.000	-
37 AccInfOFor	0	13	0.00	6	27	22.22	0	2	0.00	-	-	0.152
39 OsLam	0	11	0.00	0	22	0.00	0	1	0.00	-	-	-
40 IncaB	0	12	0.00	1	23	4.35	0	1	0.00	-	-	1.000
41 LambSutOs	4	18	22.22	18	40	45.00	2	2	100.00	1.854*	0.173	-
42 OsAst	4	19	21.05	1	34	2.94	0	2	0.00	2.800*	0.094	-
43 BregBone	0	11	0.00	0	21	0.00	0	1	0.00	-	-	-
44 CorSutOs	0	19	0.00	0	37	0.00	0	1	0.00	-	-	-
45 SagSutOs	0	10	0.00	1	14	7.14	0	1	0.00	-	-	1.000
46 EpiBone	0	11	0.00	6	21	28.57	0	1	0.00	-	-	0.071
48 OcMastSutOs	1	13	7.69	3	27	11.11	0	2	0.00	-	-	1.000
50 FroTempArt	0	17	0.00	0	28	0.00	0	1	0.00	-	-	-
51 CondFacDo	3	18	16.67	6	33	18.18	0	2	0.00	0.000*	1.000	-
52 RockJaw	4	8	50.00	7	17	41.18	1	1	100.00	-	-	1.000

Legend: *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX C - CONTINUED

Late Krotovo Developed Bronze												
	Female			Male			Unknown			Chi-square (sex difference		Fisher's
Traits	n	N	Freq	n	N	Freq	n	N	Freq	in trait freq)	p	Exact
2 MargFor	5	26	19.23	8	38	21.05	0	1	0.00	0.000*	1.000	-
3 PrecondTub	6	22	27.27	5	36	13.89	0	0	-	0.840*	0.359	-
4 OsApiLig	0	10	0.00	1	18	5.56	0	0	-	-	-	1.000
5 ClinoCBri	2	23	8.70	0	25	0.00	0	0	-	0.613*	0.434	-
8 IntCondCan	5	17	29.41	9	29	31.03	0	0	-	0.000*	1.000	-
9 AntCondCan	3	21	14.29	6	38	15.79	0	0	-	0.000*	1.000	-
10 PterABr	2	23	8.70	4	32	12.50	0	2	0.00	0.000*	0.994	-
11 PterSBr	1	23	4.35	7	30	23.33	0	2	0.00	2.330*	0.127	-
12 TrochSpur	0	27	0.00	6	42	14.29	0	2	0.00	2.617*	0.106	-
13 MylohA	3	27	11.11	4	31	12.90	0	2	0.00	0.000*	1.000	-
14 LingBri	13	26	50.00	19	31	61.29	0	2	0.00	0.732	0.392	-
18 TympDeh	13	29	44.83	1	39	2.56	0	1	0.00	15.678*	0.000†	-
19 ForOvInc	0	23	0.00	2	31	6.45	0	2	0.00	0.263*	0.608	-
20 ForSpinOp	10	23	43.48	14	31	45.16	0	2	0.00	0.015	0.902	-
21 OsJap	1	23	4.35	3	27	11.11	0	2	0.00	0.126*	0.722	-
22 Metop	1	15	6.67	0	22	0.00	0	1	0.00	-	-	0.405
24 GenPit	13	13	100.00	13	13	100.00	1	1	100.00	-	-	-
25 ParFor	18	30	60.00	31	41	75.61	0	1	0.00	1.311*	0.252	-
27 SSSTR	12	15	80.00	14	19	73.68	1	1	100.00	-	-	1.000
28 ParProcT	0	25	0.00	2	37	5.41	0	1	0.00	0.202*	0.653	-
31 ZygFacFor	4	24	16.67	6	34	17.65	2	2	100.00	0.000*	1.000	-
32 SupOrbFor	4	28	14.29	4	42	9.52	0	2	0.00	0.053*	0.818	-
34 AccSupOFor	0	28	0.00	1	42	2.38	0	2	0.00	0.000*	1.000	-
37 AccInfOFor	3	16	18.75	12	21	57.14	0	2	0.00	4.074*	0.044†	-
39 OsLam	1	13	7.69	0	18	0.00	0	0	-	-	-	0.419
40 IncaB	0	15	0.00	0	19	0.00	0	1	0.00	-	-	-
41 LambSutOs	12	25	48.00	7	32	21.88	0	1	0.00	3.215*	0.073	-
42 OsAst	1	23	4.35	8	32	25.00	0	1	0.00	2.798*	0.094	-
43 BregBone	0	13	0.00	0	18	0.00	0	1	0.00	-	-	-
44 CorSutOs	0	22	0.00	0	30	0.00	0	2	0.00	-	-	-
45 SagSutOs	0	14	0.00	2	14	14.29	0	0	-	-	-	0.481
46 EpiBone	2	16	12.50	2	24	8.33	0	2	0.00	-	-	1.000
48 OcMastSutOs	1	18	5.56	1	24	4.17	0	0	-	0.000*	1.000	-
50 FroTempArt	0	21	0.00	0	25	0.00	1	2	50.00	-	-	-
51 CondFacDo	3	20	15.00	20	35	57.14	0	0	-	7.639*	0.006†	-
52 RockJaw	9	12	75.00	7	17	41.18	1	1	100.00	2.030*	0.154	-

Legend: *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX C - CONTINUED

Andronovo Developed Bronze												
	Female			Male			Unknown			Chi-square (sex difference in trait freq)		Fisher's Exact
Traits	n	N	Freq	n	N	Freq	n	N	Freq		p	
2 MargFor	1	13	7.69	1	14	7.14	0	3	0.00	-	-	1.000
3 PrecondTub	4	9	44.44	2	12	16.67	0	2	0.00	-	-	0.331
4 OsApiLig	0	4	0.00	2	5	40.00	0	1	0.00	-	-	0.444
5 ClinoCBri	0	7	0.00	0	13	0.00	0	2	0.00	-	-	-
8 IntCondCan	5	8	62.50	7	10	70.00	0	2	0.00	-	-	1.000
9 AntCondCan	4	11	36.36	0	11	0.00	0	2	0.00	-	-	0.090
10 PterABr	1	11	9.09	3	13	23.08	0	3	0.00	-	-	0.596
11 PterSBr	0	10	0.00	1	13	7.69	0	3	0.00	-	-	1.000
12 TrochSpur	0	11	0.00	1	14	7.14	0	6	0.00	-	-	1.000
13 MylohA	1	10	10.00	2	14	14.29	0	3	0.00	-	-	1.000
14 LingBri	6	8	75.00	13	14	92.86	1	3	33.33	-	-	0.527
18 TympDeh	1	14	7.14	4	14	28.57	0	5	0.00	-	-	0.326
19 ForOvInc	0	11	0.00	2	13	15.38	0	3	0.00	-	-	0.482
20 ForSpinOp	5	10	50.00	2	13	15.38	2	3	66.67	-	-	0.169
21 OsJap	0	7	0.00	0	12	0.00	0	3	0.00	-	-	-
22 Metop	0	7	0.00	0	8	0.00	0	3	0.00	-	-	-
24 GenPit	7	7	100.00	5	6	83.33	1	1	100.00	-	-	0.462
25 ParFor	6	16	37.50	11	14	78.57	1	6	16.67	3.593*	0.058	-
27 SSSTR	5	8	62.50	6	8	75.00	2	2	100.00	-	-	1.000
28 ParProcT	0	10	0.00	0	15	0.00	0	2	0.00	-	-	-
31 ZygFacFor	5	11	45.45	4	16	25.00	0	3	0.00	-	-	0.411
32 SupOrbFor	1	14	7.14	6	15	40.00	0	6	0.00	-	-	0.080
34 AccSupOFor	1	14	7.14	0	13	0.00	0	6	0.00	-	-	1.000
37 AccInfOFor	0	5	0.00	2	14	14.29	0	2	0.00	-	-	1.000
39 OsLam	0	7	0.00	0	6	0.00	0	2	0.00	-	-	-
40 IncaB	0	8	0.00	0	8	0.00	0	3	0.00	-	-	-
41 LambSutOs	4	16	25.00	3	12	25.00	2	4	50.00	-	-	1.000
42 OsAst	1	12	8.33	3	12	25.00	0	5	0.00	-	-	0.590
43 BregBone	0	6	0.00	0	7	0.00	0	2	0.00	-	-	-
44 CorSutOs	0	10	0.00	1	13	7.69	0	4	0.00	-	-	1.000
45 SagSutOs	0	7	0.00	0	5	0.00	0	2	0.00	-	-	-
46 EpiBone	2	7	28.57	1	10	10.00	0	1	0.00	-	-	0.537
48 OcMastSutOs	0	7	0.00	0	7	0.00	0	1	0.00	-	-	-
50 FroTempArt	2	7	28.57	0	11	0.00	0	1	0.00	-	-	0.137
51 CondFacDo	3	7	42.86	0	9	0.00	0	2	0.00	-	-	0.063
52 RockJaw	3	5	60.00	1	7	14.29	1	2	50.00	-	-	0.222

Legend: *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX D - THE SIDE AND SYMMETRY DATA, INDEX OF BILATERALITY, SIDE TO SIDE CORRELATION AND CHI-SQUARED VALUES FOR 27 BILATERAL VARIANTS

Pooled Sample of Siberian Crania													
						Index of	Test for Independence		Chi Square (side difference		Chi Square (side to side		Fisher
Trait	a	b	c	d	total	Bilaterality	ϕ	r2	in trait freq)	p	dependence)	p	Exact
2 MargFor	17	19	10	162	208	36.96	0.466	0.217	2.793	0.095	41.597*	0.000†	-
3 PrecondTub	23	18	10	143	194	45.10	0.539	0.291	2.286	0.131	52.808*	0.000†	-
5 ClinoCBri	4	4	2	113	123	40.00	0.552	0.305	0.667	0.414	27.864*	0.000†	-
8 IntCondCan	40	22	10	62	134	55.56	0.522	0.272	4.500	0.034†	36.505	0.000†	-
9 AntCondCan	20	29	18	133	200	29.85	0.317	0.100	2.574	0.109	18.238*	0.000†	-
10 PterABr	16	14	18	113	161	33.33	0.378	0.143	0.500	0.480	20.655*	0.000†	-
11 PterSBr	3	5	12	123	143	15.00	0.215	0.046	2.882	0.090	3.890*	0.049†	-
12 TrochSpur	9	2	11	220	242	40.91	0.583	0.340	6.231	0.013†	72.385*	0.000†	-
13 MylohA	9	8	6	160	183	39.13	0.522	0.272	0.286	0.593	43.523*	0.000†	-
14 LingBri	89	21	15	53	178	71.20	0.580	0.336	1.000	0.317	59.917	0.000†	-
18 TympDeh	17	19	11	206	253	36.17	0.469	0.220	2.133	0.144	51.544*	0.000†	-
19 ForOvInc	3	6	3	142	154	25.00	0.379	0.144	1.000	0.317	14.560*	0.000†	-
20 ForSpinOp	33	27	18	72	150	42.31	0.362	0.131	1.800	0.180	19.652	0.000†	-
21 OsJap	7	2	4	97	110	53.85	0.674	0.454	0.667	0.414	42.166*	0.000†	-
25 ParFor	169	22	36	33	260	74.45	0.393	0.154	3.379	0.066	40.063	0.000†	-
28 ParProcT	1	2	0	164	167	33.33	0.574	0.329	2.000	0.157	13.251*	0.000†	-
31 ZygFacFor	14	22	19	104	159	25.45	0.242	0.059	0.220	0.639	7.934*	0.005†	-
32 SupOrbFor	19	16	20	207	262	34.55	0.435	0.189	0.444	0.505	45.972*	0.000†	-
34 AccSupOFor	1	8	7	221	237	6.25	0.085	0.007	0.067	0.796	0.136*	0.712	-
37 AccInfOFor	24	14	8	62	108	52.17	0.541	0.293	1.636	0.201	31.609	0.000†	-
41 LambSutOs	45	27	19	97	188	49.45	0.473	0.224	1.391	0.238	42.086	0.000†	-
42 OsAst	6	13	9	137	165	21.43	0.282	0.080	0.727	0.394	10.244*	0.001†	-
44 CorSutOs	1	4	1	166	172	16.67	0.304	0.092	1.800	0.180	3.499*	0.061	-
46 EpiBone	5	6	6	77	94	29.41	0.382	0.146	0.000	1.000	10.285*	0.001†	-
48 OcMastSutOs	0	4	9	79	92	0.00	-0.166	0.028	1.923	0.166	0.000*	1.000	-
50 FroTempArt	1	1	1	128	131	33.33	0.492	0.242	0.000	1.000	7.444*	0.006†	-
51 CondFacDo	34	11	8	107	160	64.15	0.701	0.491	0.474	0.491	78.620	0.000†	-

Legend: a- common presence; b- present right, absent left; c- absent right, present left; d- common absence; * Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX D - CONTINUED

Eneolithic													
Trait	a	b	c	d	total	Index of Bilaterality	Test for Independence ϕ	Test for Independence r2	Chi Square (side difference in trait freq)	p	Chi Square (side to side dependence)	p	Fisher Exact
2 MargFor	2	5	2	44	53	22.22	0.310	0.096	1.286	0.257	2.227*	0.136	-
3 PrecondTub	6	3	4	34	47	46.15	0.540	0.291	0.143	0.705	10.546*	0.001†	-
5 ClinoCBri	2	0	1	21	24	66.67	0.798	0.636	1.000	0.317	-	-	0.011†
8 IntCondCan	10	5	2	14	31	58.82	0.556	0.309	1.286	0.257	7.427*	0.006†	-
9 AntCondCan	5	6	4	31	46	33.33	0.366	0.134	0.400	0.527	4.185*	0.041†	-
10 PterABr	3	6	4	27	40	23.08	0.225	0.050	0.400	0.527	-	-	0.316
11 PterSBr	1	1	3	33	38	20.00	0.303	0.092	1.000	0.317	-	-	0.202
12 TrochSpur	3	1	5	46	55	33.33	0.480	0.231	2.667	0.102	7.981*	0.005†	-
13 MylohA	2	1	1	39	43	50.00	0.642	0.412	0.000	1.000	9.198*	0.002†	-
14 LingBri	21	8	0	17	46	72.41	0.702	0.492	8.000	0.005†	19.826*	0.000†	-
18 TympDeh	1	4	1	50	56	16.67	0.277	0.077	1.800	0.180	0.659*	0.417	-
19 ForOvInc	1	1	0	37	39	50.00	0.698	0.487	1.000	0.317	-	-	0.051
20 ForSpinOp	4	6	6	21	37	25.00	0.178	0.032	0.000	1.000	-	-	0.407
21 OsJap	3	0	2	23	28	60.00	0.743	0.552	2.000	0.157	-	-	0.003†
25 ParFor	37	7	9	5	58	69.81	0.209	0.044	0.250	0.617	1.475*	0.225	-
28 ParProcT	0	1	0	36	37	0.00	-	-	1.000	0.317	-	-	-
31 ZygFacFor	3	9	4	20	36	18.75	0.099	0.010	1.923	0.166	-	-	0.664
32 SupOrbFor	8	7	4	41	60	42.11	0.481	0.231	0.818	0.366	11.250*	0.001†	-
34 AccSupOFor	0	2	1	48	51	0.00	-0.029	0.001	0.333	0.564	0.000*	1.000	-
37 AccInfOFor	3	1	4	13	21	37.50	0.429	0.184	1.800	0.180	-	-	0.088
41 LambSutOs	10	9	1	17	37	50.00	0.515	0.265	6.400	0.011†	7.681*	0.006†	-
42 OsAst	2	4	1	32	39	28.57	0.410	0.168	1.800	0.180	-	-	0.056
44 CorSutOs	1	1	0	28	30	50.00	0.695	0.483	1.000	0.317	-	-	0.067
46 EpiBone	1	0	2	19	22	33.33	0.549	0.302	2.000	0.157	-	-	0.136
48 OcMastSutOs	0	2	1	13	16	0.00	-0.098	0.010	0.333	0.564	-	-	1.000
50 FroTempArt	0	0	0	31	31	-	-	-	-	-	-	-	-
51 CondFacDo	10	3	1	26	40	71.43	0.768	0.590	1.000	0.317	-	-	0.000†

Legend: a- common presence; b- present right, absent left; c- absent right, present left; d- common absence; *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX D - CONTINUED

Developed Krotovo (Locality 1)													
Trait	a	b	c	d	total	Index of Bilaterality	Test for Independence ϕ	r2	Chi Square (side difference in trait freq)	p	Chi Square (side to side dependence)	p	Fisher Exact
2 MargFor	3	4	5	40	52	25.00	0.300	0.090	0.111	0.739	2.568*	0.109	-
3 PrecondTub	3	4	3	42	52	30.00	0.387	0.149	0.143	0.705	4.632*	0.031†	-
5 ClinoCBri	1	1	0	26	28	50.00	0.694	0.481	1.000	0.317	-	-	0.071
8 IntCondCan	8	4	2	16	30	57.14	0.577	0.333	0.667	0.414	-	-	0.004†
9 AntCondCan	3	7	7	35	52	17.65	0.133	0.018	0.000	1.000	0.265*	0.606	-
10 PterABr	6	3	5	29	43	42.86	0.484	0.235	0.500	0.480	7.548*	0.006†	-
11 PterSBr	0	1	3	33	37	0.00	-0.050	0.002	1.000	0.317	-	-	1.000
12 TrochSpur	0	0	2	61	63	0.00	-	-	2.000	0.157	-	-	-
13 MylohA	0	3	1	42	46	0.00	-0.039	0.002	1.000	0.317	0.000*	1.000	-
14 LingBri	20	4	7	12	43	64.52	0.478	0.228	0.818	0.366	7.922*	0.005†	-
18 TympDeh	3	6	5	57	71	21.43	0.266	0.071	0.091	0.763	2.810*	0.094	-
19 ForOvInc	0	2	2	36	40	0.00	-0.053	0.003	0.000	1.000	-	-	1.000
20 ForSpinOp	12	9	3	16	40	50.00	0.427	0.182	3.000	0.083	5.621*	0.018†	-
21 OsJap	3	1	1	22	27	60.00	0.707	0.499	0.000	1.000	-	-	0.005†
25 ParFor	49	4	10	9	72	77.78	0.456	0.208	2.571	0.109	12.419*	0.000†	-
28 ParProcT	0	1	0	42	43	0.00	-	-	1.000	0.317	-	-	-
31 ZygFacFor	1	5	10	27	43	6.25	-0.082	0.007	1.667	0.197	0.001*	0.972	-
32 SupOrbFor	2	4	5	58	69	18.18	0.237	0.056	0.111	0.739	1.591*	0.207	-
34 AccSupOFor	0	3	1	62	66	0.00	-0.027	0.001	1.000	0.317	0.000*	1.000	-
37 AccInfOFor	11	5	1	12	29	64.71	0.617	0.380	2.667	0.102	8.650*	0.003†	-
41 LambSutOs	10	6	5	27	48	47.62	0.477	0.227	0.091	0.763	8.836*	0.003†	-
42 OsAst	2	2	1	32	37	40.00	0.534	0.286	0.333	0.564	-	-	0.026†
44 CorSutOs	0	1	0	43	44	0.00	-	-	1.000	0.317	-	-	-
46 EpiBone	1	1	1	17	20	33.33	0.444	0.198	0.000	1.000	-	-	0.195
48 OcMastSutOs	0	1	2	14	17	0.00	-0.091	0.008	0.333	0.564	-	-	1.000
50 FroTempArt	0	0	0	32	32	-	-	-	-	-	-	-	-
51 CondFacDo	9	4	5	22	40	50.00	0.498	0.248	0.111	0.739	-	-	0.004†

Legend: a- common presence; b- present right, absent left; c- absent right, present left; d- common absence; *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX D - CONTINUED

Developed Krotovo (Locality 2) Without Kurgan													
Trait	a	b	c	d	total	Index of Bilaterality	Test for Independence ϕ	r2	Chi Square (side difference in trait freq)	p	Chi Square (side to side dependence)	p	Fisher Exact
2 MargFor	3	4	1	24	32	37.50	0.486	0.236	1.800	0.180	-	-	0.025†
3 PrecondTub	2	4	1	25	32	28.57	0.395	0.156	1.800	0.180	-	-	0.083
5 ClinoCBri	0	0	0	16	16	-	-	-	-	-	-	-	-
8 IntCondCan	5	4	2	13	24	45.45	0.450	0.202	0.667	0.414	-	-	0.061
9 AntCondCan	3	8	4	22	37	20.00	0.139	0.019	1.333	0.248	-	-	0.403
10 PterABr	2	1	1	17	21	50.00	0.611	0.373	0.000	1.000	-	-	0.041†
11 PterSBr	0	0	0	15	15	-	-	-	-	-	-	-	-
12 TrochSpur	1	0	1	39	41	50.00	0.698	0.488	1.000	0.317	4.498*	0.034†	-
13 MylohA	2	2	3	23	30	28.57	0.351	0.123	0.200	0.655	-	-	0.119
14 LingBri	17	4	1	6	28	77.27	0.602	0.363	1.800	0.180	-	-	0.003†
18 TympDeh	6	4	1	34	45	54.55	0.655	0.430	1.800	0.180	15.229*	0.000†	-
19 ForOvInc	0	1	0	20	21	0.00	-	-	1.000	0.317	-	-	-
20 ForSpinOp	3	4	3	8	18	30.00	0.161	0.026	0.143	0.705	-	-	0.627
21 OsJap	0	0	0	11	11	-	-	-	-	-	-	-	-
25 ParFor	33	5	3	2	43	80.49	0.233	0.054	0.500	0.480	0.782*	0.377	-
28 ParProcT	0	0	0	23	23	-	-	-	-	-	-	-	-
31 ZygFacFor	3	2	1	14	20	50.00	0.577	0.333	0.333	0.564	-	-	0.032†
32 SupOrbFor	3	0	5	36	44	37.50	0.574	0.329	5.000	0.025†	9.187*	0.002†	-
34 AccSupOFor	1	0	1	35	37	50.00	0.697	0.486	1.000	0.317	-	-	0.054
37 AccInfOFor	2	2	2	8	14	33.33	0.300	0.090	0.000	1.000	-	-	0.520
41 LambSutOs	8	2	7	16	33	47.06	0.457	0.209	2.778	0.096	-	-	0.020†
42 OsAst	0	1	1	26	28	0.00	-0.037	0.001	0.000	1.000	-	-	1.000
44 CorSutOs	0	1	1	32	34	0.00	-0.030	0.001	0.000	1.000	-	-	1.000
46 EpiBone	0	1	1	11	13	0.00	-0.083	0.007	0.000	1.000	-	-	1.000
48 OcMastSutOs	0	0	1	15	16	0.00	-	-	1.000	0.317	-	-	-
50 FroTempArt	0	1	0	17	18	0.00	-	-	1.000	0.317	-	-	-
51 CondFacDo	2	1	0	24	27	66.67	0.800	0.640	1.000	0.317	-	-	0.009†

Legend: a- common presence; b- present right, absent left; c- absent right, present left; d- common absence; *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX D - CONTINUED

Developed Krotovo (Locality 2) With Kurgan													
Trait	a	b	c	d	total	Index of Bilaterality	Test for Independence φ	r2	Chi Square (side difference in trait freq)	p	Chi Square (side to side dependence)	p	Fisher Exact
2 MargFor	5	1	1	23	30	71.43	0.792	0.627	0.000	1.000	-	-	0.000†
3 PrecondTub	6	4	1	14	25	54.55	0.582	0.339	1.800	0.180	-	-	0.007†
5 ClinoCBri	0	3	1	19	23	0.00	-0.083	0.007	1.000	0.317	-	-	1.000
8 IntCondCan	9	4	1	7	21	64.29	0.552	0.304	1.800	0.180	-	-	0.024†
9 AntCondCan	6	3	2	15	26	54.55	0.566	0.320	0.200	0.655	-	-	0.008†
10 PterABr	5	1	3	13	22	55.56	0.598	0.358	1.000	0.317	-	-	0.011†
11 PterSBr	0	2	2	16	20	0.00	-0.111	0.012	0.000	1.000	-	-	1.000
12 TrochSpur	3	1	0	31	35	75.00	0.852	0.727	1.000	0.317	-	-	0.001†
13 MylohA	1	1	0	21	23	50.00	0.691	0.477	1.000	0.317	-	-	0.087
14 LingBri	10	1	4	8	23	66.67	0.589	0.347	1.800	0.180	-	-	0.009†
18 TympDeh	0	2	2	30	34	0.00	-0.063	0.004	0.000	1.000	-	-	1.000
19 ForOvInc	1	0	1	18	20	50.00	0.688	0.474	1.000	0.317	-	-	0.100
20 ForSpinOp	5	2	2	13	22	55.56	0.581	0.338	0.000	1.000	-	-	0.014†
21 OsJap	0	1	1	12	14	0.00	-0.077	0.006	0.000	1.000	-	-	1.000
25 ParFor	25	2	4	4	35	80.65	0.475	0.225	0.667	0.414	-	-	0.016†
28 ParProcT	0	0	0	24	24	-	-	-	-	-	-	-	-
31 ZygFacFor	1	3	2	15	21	16.67	0.149	0.022	0.200	0.655	-	-	0.489
32 SupOrbFor	4	0	1	31	36	80.00	0.880	0.775	1.000	0.317	-	-	0.000†
34 AccSupOFor	0	2	3	27	32	0.00	-0.083	0.007	0.200	0.655	-	-	1.000
37 AccInfOFor	2	2	0	14	18	50.00	0.661	0.438	2.000	0.157	-	-	0.039†
41 LambSutOs	10	2	2	14	28	71.43	0.708	0.502	0.000	1.000	11.305*	0.001†	-
42 OsAst	1	2	1	21	25	25.00	0.345	0.119	0.333	0.564	-	-	0.230
44 CorSutOs	0	0	0	26	26	-	-	-	-	-	-	-	-
46 EpiBone	1	2	1	9	13	25.00	0.272	0.074	0.333	0.564	-	-	0.423
48 OcMastSutOs	0	0	4	13	17	0.00	-	-	4.000	0.046†	-	-	-
50 FroTempArt	0	0	0	20	20	-	-	-	-	-	-	-	-
51 CondFacDo	4	0	1	16	21	80.00	0.868	0.753	1.000	0.317	-	-	0.001†

Legend: a- common presence; b- present right, absent left; c- absent right, present left; d- common absence; *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX D - CONTINUED

Late Krotovo Developed Bronze													
Trait	a	b	c	d	total	Index of Bilaterality	Test for Independence ϕ	r2	Chi Square (side difference in trait freq)	p	Chi Square (side to side dependence)	p	Fisher Exact
2 MargFor	4	4	0	21	29	50.00	0.648	0.420	4.000	0.046†	-	-	0.003†
3 PrecondTub	4	2	1	20	27	57.14	0.663	0.439	0.333	0.564	-	-	0.004†
5 ClinoCBri	1	0	0	21	22	100.00	1.000	1.000	0.000	1.000	-	-	0.045†
8 IntCondCan	3	4	2	10	19	33.33	0.287	0.082	0.667	0.414	-	-	0.305
9 AntCondCan	2	3	1	22	28	33.33	0.441	0.195	1.000	0.317	-	-	0.073
10 PterABr	0	1	4	19	24	0.00	-0.093	0.009	1.800	0.180	-	-	1.000
11 PterSBr	2	0	4	17	23	33.33	0.519	0.270	4.000	0.046†	-	-	0.059
12 TrochSpur	2	0	2	30	34	50.00	0.685	0.469	2.000	0.157	-	-	0.011†
13 MylohA	3	0	1	24	28	75.00	0.849	0.720	1.000	0.317	-	-	0.001†
14 LingBri	13	1	3	10	27	76.47	0.710	0.504	1.000	0.317	-	-	0.000†
18 TympDeh	5	2	2	24	33	55.56	0.637	0.406	0.000	1.000	-	-	0.002†
19 ForOvInc	0	2	0	21	23	0.00	-	-	2.000	0.157	-	-	-
20 ForSpinOp	6	6	2	9	23	42.86	0.334	0.111	2.000	0.157	-	-	0.193
21 OsJap	1	0	0	21	22	100.00	1.000	1.000	0.000	1.000	-	-	0.045†
25 ParFor	20	3	5	7	35	71.43	0.476	0.226	0.500	0.480	-	-	0.015†
28 ParProcT	1	0	0	28	29	100.00	1.000	1.000	0.000	1.000	-	-	0.034†
31 ZygFacFor	3	1	2	20	26	50.00	0.603	0.364	0.333	0.564	-	-	0.014†
32 SupOrbFor	1	2	4	29	36	14.29	0.170	0.029	0.667	0.414	-	-	0.370
34 AccSupOFor	0	1	0	34	35	0.00	-	-	1.000	0.317	-	-	-
37 AccInfOFor	5	4	1	8	18	50.00	0.471	0.222	1.800	0.180	-	-	0.131
41 LambSutOs	6	3	2	15	26	54.55	0.566	0.320	0.200	0.655	-	-	0.008†
42 OsAst	1	1	4	18	24	16.67	0.217	0.047	1.800	0.180	-	-	0.380
44 CorSutOs	0	0	0	26	26	-	-	-	-	-	-	-	-
46 EpiBone	1	1	1	16	19	33.33	0.441	0.195	0.000	1.000	-	-	0.205
48 OcMastSutOs	0	1	1	18	20	0.00	-0.053	0.003	0.000	1.000	-	-	1.000
50 FroTempArt	0	0	1	21	22	0.00	-	-	1.000	0.317	-	-	-
51 CondFacDo	8	3	1	12	24	66.67	0.669	0.448	1.000	0.317	-	-	0.002†

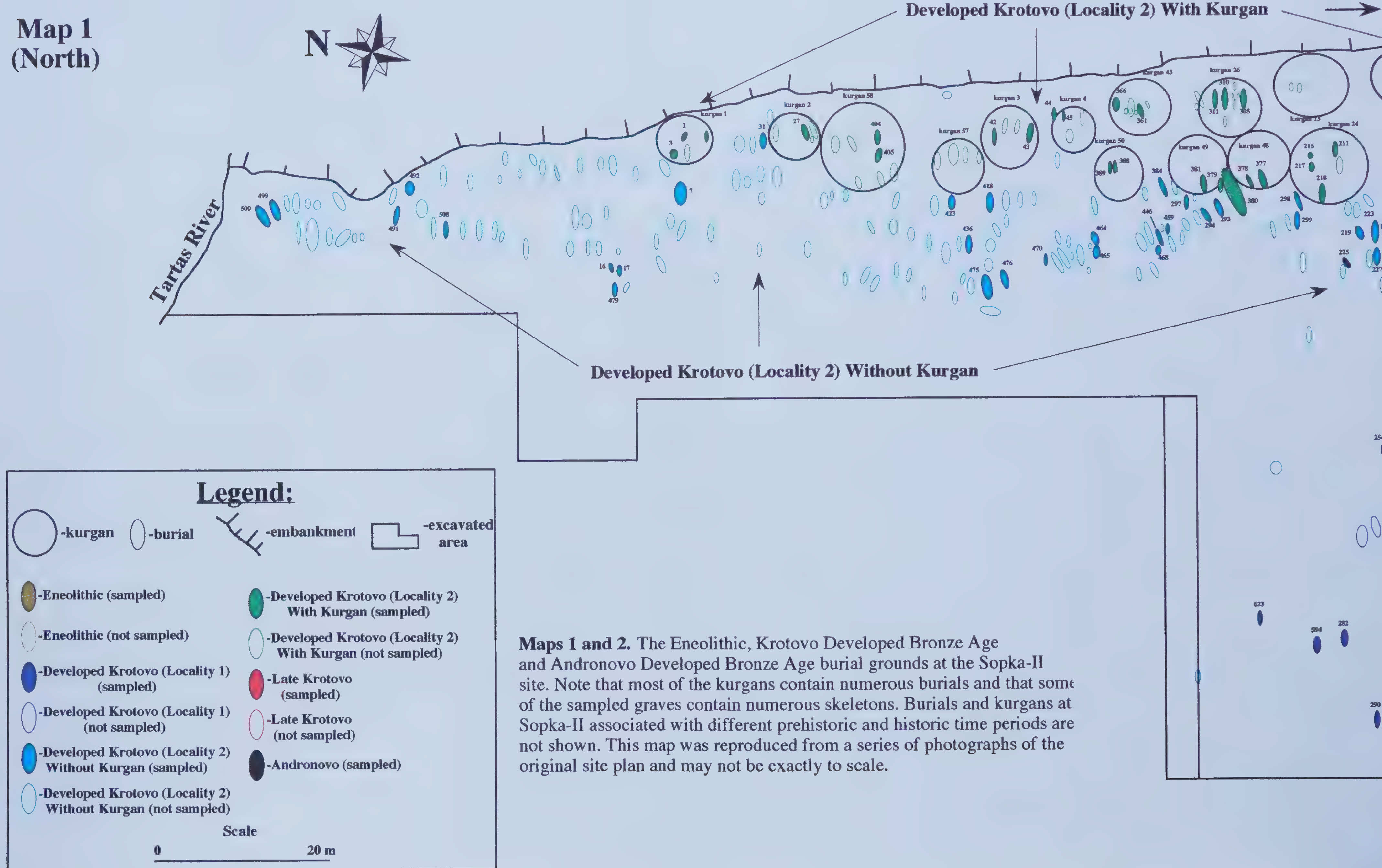
Legend: a- common presence; b- present right, absent left; c- absent right, present left; d- common absence; *- Yate's Correction for Continuity; †- significance at the 5% level.

APPENDIX D - CONTINUED

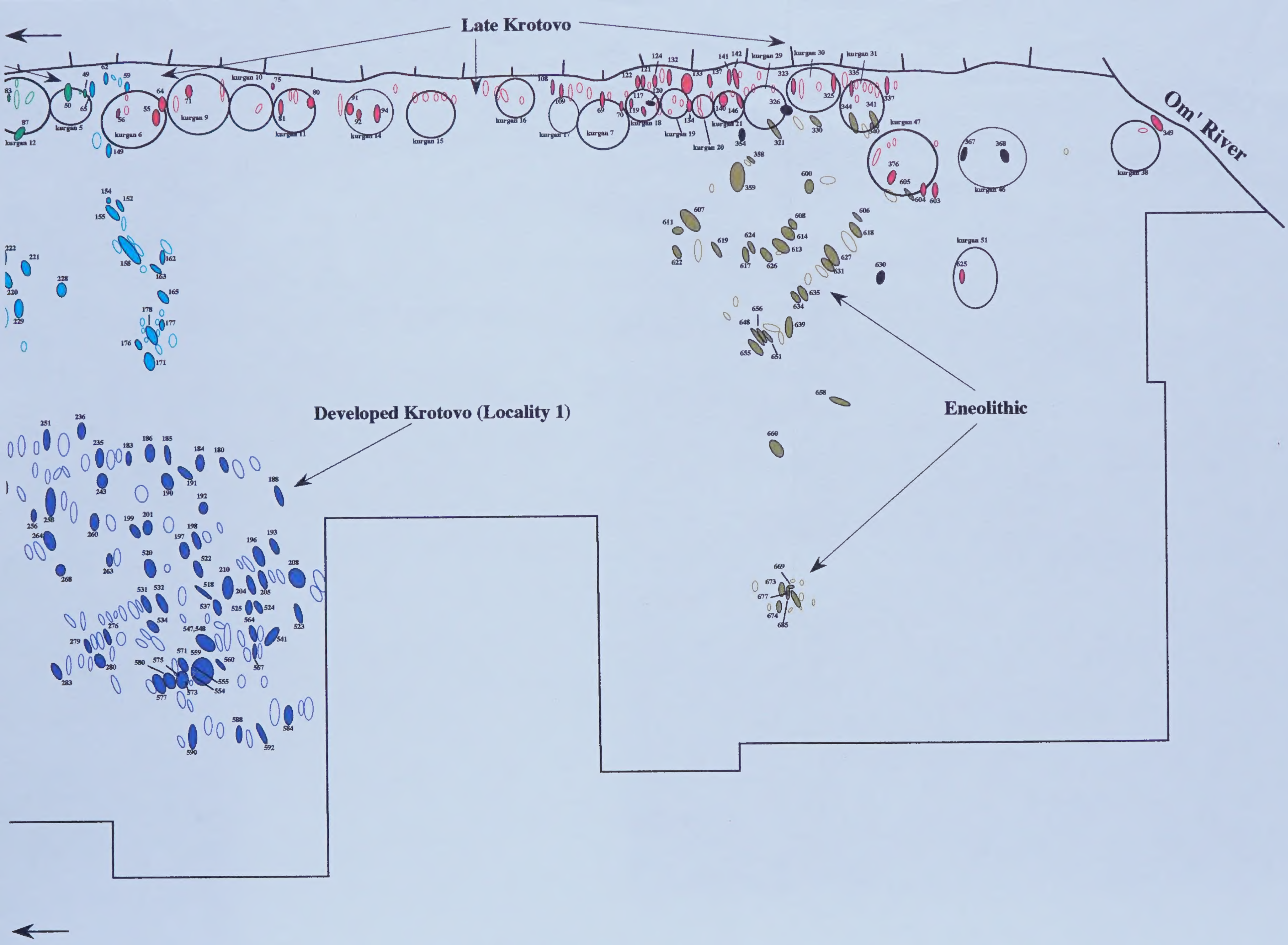
Andronovo Developed Bronze													
Trait	a	b	c	d	total	Index of Bilaterality	Test for Independence φ	r2	Chi Square (side difference in trait freq)	p	Chi Square (side to side dependence)	p	Fisher Exact
2 MargFor	0	1	1	10	12	0.00	-0.091	0.008	0.000	1.000	-	-	1.000
3 PrecondTub	2	1	0	8	11	66.67	0.770	0.593	1.000	0.317	-	-	0.055
5 ClinoCBri	0	0	0	10	10	-	-	-	-	-	-	-	-
8 IntCondCan	5	1	1	2	9	71.43	0.500	0.250	0.000	1.000	-	-	0.226
9 AntCondCan	1	2	0	8	11	33.33	0.516	0.267	2.000	0.157	-	-	0.273
10 PterABr	0	2	1	8	11	0.00	-0.149	0.022	0.333	0.564	-	-	1.000
11 PterSBr	0	1	0	9	10	0.00	-	-	1.000	0.317	-	-	-
12 TrochSpur	0	0	1	13	14	0.00	-	-	1.000	0.317	-	-	-
13 MylohA	1	1	0	11	13	50.00	0.677	0.458	1.000	0.317	-	-	0.154
14 LingBri	8	3	0	0	11	72.73	-	-	3.000	0.083	-	-	-
18 TympDeh	2	1	0	11	14	66.67	0.782	0.611	1.000	0.317	-	-	0.033†
19 ForOvInc	1	0	0	10	11	100.00	1.000	1.000	0.000	1.000	-	-	0.091
20 ForSpinOp	3	0	2	5	10	60.00	0.655	0.429	2.000	0.157	-	-	0.167
21 OsJap	0	0	0	8	8	-	-	-	-	-	-	-	-
25 ParFor	5	1	5	6	17	45.45	0.368	0.135	2.667	0.102	-	-	0.304
28 ParProcT	0	0	0	11	11	-	-	-	-	-	-	-	-
31 ZygFacFor	3	2	0	8	13	60.00	0.693	0.480	2.000	0.157	-	-	0.035†
32 SupOrbFor	1	3	1	12	17	20.00	0.228	0.052	1.000	0.317	-	-	0.426
34 AccSupOFor	0	0	1	15	16	0.00	-	-	1.000	0.317	-	-	-
37 AccInfOFor	1	0	0	7	8	100.00	1.000	1.000	0.000	1.000	-	-	0.125
41 LambSutOs	1	5	2	8	16	12.50	-0.041	0.002	1.286	0.257	-	-	1.000
42 OsAst	0	3	1	8	12	0.00	-0.174	0.030	1.000	0.317	-	-	1.000
44 CorSutOs	0	1	0	11	12	0.00	-	-	1.000	0.317	-	-	-
46 EpiBone	1	1	0	5	7	50.00	0.645	0.417	1.000	0.317	-	-	0.286
48 OcMastSutOs	0	0	0	6	6	-	-	-	-	-	-	-	-
50 FroTempArt	1	0	0	7	8	100.00	1.000	1.000	0.000	1.000	-	-	0.125
51 CondFacDo	1	0	0	7	8	100.00	1.000	1.000	0.000	1.000	-	-	0.125

Legend: a- common presence; b- present right, absent left; c- absent right, present left; d- common absence; *- Yate's Correction for Continuity; †- significance at the 5% level.

Map 1 (North)



Maps 1 and 2. The Eneolithic, Krotovo Developed Bronze Age and Andronovo Developed Bronze Age burial grounds at the Sopka-II site. Note that most of the kurgans contain numerous burials and that some of the sampled graves contain numerous skeletons. Burials and kurgans at Sopka-II associated with different prehistoric and historic time periods are not shown. This map was reproduced from a series of photographs of the original site plan and may not be exactly to scale.


Late Krotovo
Developed Krotovo (Locality 1)
Eneolithic
Om' River

Map 2
(South)